AD-A038 329 SCRIPPS INSTITUTION OF OCEANOGRAPHY SAN DIEGO CALIF --ETC F/G 8/10
CRUISE REPORT, INDOPAC EXPEDITION, LEGS 4, 5, 6, 7, AND 8.(U)
MAR 77 G G SHOR, S M SMITH N00014-75-C-0749

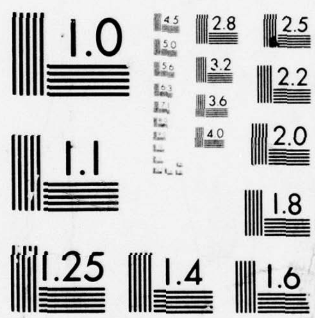
UNCLASSIFIED MPL-U-30/77 NL

1 OF 1

AD
A038 329

END

DATE
FILMED
5-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MARINE PHYSICAL LABORATORY
of the Scripps Institution of Oceanography
San Diego, California 92152

CRUISE REPORT, INDOPAC EXPEDITION
LEGS 4, 5, 6, 7, AND 8

Edited by

George G. Shor, Jr. and Stuart M. Smith

Sponsored by
Office of Naval Research
and
National Science Foundation

31 March 1977

SIO Reference 77-5

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
SIO Reference 77-5

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE *(and Subtitle)*
6 CRUISE REPORT, INDOPAC EXPEDITION, LEGS 4, 5, 6, 7, and 8,

5. TYPE OF REPORT & PERIOD COVERED
9 Summary rept.,

6. ~~PERFORMING ORG. REPORT NUMBER~~
14 MPL-U-30/77, SIO-Ref-77-5

7. AUTHOR(s)
10 George G. Shor, Jr. [redacted] Stuart M. Smith

8. ~~CONTRACT OR GRANT NUMBER(s)~~
National Science Foundation & Office of Naval Research
*(See #18)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
University of California, San Diego, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, California 92152

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research, Code 222, Department of the Navy, Arlington, Virginia 22217

12. ~~REPORT DATE~~
11 31 Mar[redacted]77

13. ~~NUMBER OF PAGES~~
27 12 36p.

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*

15. SECURITY CLASS. *(of this report)*
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Document cleared for public release and sale; its distribution is unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

*NSF OCE 75-19148, 75-19387, INT 76-14749, OCE 74-22089, OCE 76-02036, OCE 74-01830, and OCE 74-02888. ~~ONR~~ N00014-75-C-0749, N00014-75-C-0704, N00014-75-C-0152. 15

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Geophysical, Geological, Physical Oceanography

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

In the summer of 1976, the R/V THOMAS WASHINGTON of the Scripps Institution of Oceanography carried out a series of geophysical, geological, and physical oceanographic programs in the marginal basins between the Pacific Ocean and Asia, on legs 4 through 8 of INDOPAC Expedition. Work was in the Philippine, South China, Sulu, Celebes, Molucca, Banda, and Arafura Seas. This report includes chronology of work, cruise tracks, lists of samples, stations, and observations, and some preliminary results. Among the significant

(continued) next page

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

217400

cont

preliminary results were the sampling of metamorphic rocks along the Yap island arc; the observation of anomalous crustal structure beneath the Philippine Sea and the Okinawa Trough; measurement of about 10 km of melange material in the Molucca Sea, which at the edges thrusts up over the arcs on either side of the Molucca Sea; observation of continental crust beneath the Timor-Tanimbar-Aru troughs. A turbidity current was recorded by current meters off the Abra delta of Luzon. Strong south-flowing currents were recorded showing transport of water through Lifamatola Strait from the Pacific to the Indian Ocean. Work on leg 5 was in cooperation with the R/V CHIU LIEN of National Taiwan University; work on leg 8 was in cooperation with the R/V ATLANTIS II of Woods Hole Oceanographic Institution.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
MARINE PHYSICAL LABORATORY OF THE
SCRIPPS INSTITUTION OF OCEANOGRAPHY
SAN DIEGO, CALIFORNIA 92152

CRUISE REPORT, INDOPAC EXPEDITION
LEGS 4, 5, 6, 7, AND 8

Edited by

George G. Shor, Jr. and Stuart M. Smith

Sponsored by
Office of Naval Research
and
National Science Foundation

SIO REFERENCE 77-5

31 March 1977

F. N. SPIESS, DIRECTOR
MARINE PHYSICAL LABORATORY

MPL-U-30/77

CRUISE REPORT, INDOPAC EXPEDITION, LEGS 4, 5, 6, 7, AND 8

edited by

George G. Shor, Jr. and Stuart M. Smith

University of California, San Diego
Marine Physical Laboratory of the
Scripps Institution of Oceanography
San Diego, California 92152

ABSTRACT

In the summer of 1976, the R/V THOMAS WASHINGTON of the Scripps Institution of Oceanography carried out a series of geophysical, geological, and physical oceanographic programs in the marginal basins between the Pacific Ocean and Asia, on legs 4 through 8 of INDOPAC Expedition. Work was in the Philippine, South China, Sulu, Celebes, Molucca, Banda, and Arafura Seas. This report includes chronology of work, cruise tracks, lists of samples, stations, and observations, and some preliminary results. Among the significant preliminary results were the sampling of metamorphic rocks along the Yap island arc; the observation of anomalous crustal structure beneath the Philippine Sea and the Okinawa Trough; measurement of about 10 km of melange material in the Molucca Sea, which at the edges thrusts up over the arcs on either side of the Molucca Sea; observation of continental crust beneath the Timor-Tanimbar-Aru troughs. A turbidity current was recorded by current meters off the Abra delta of Luzon. Strong south-flowing currents were recorded showing transport of water through Lifamatola Strait from the Pacific to the Indian Ocean. Work on leg 5 was in cooperation with the R/V *CHIU LIEN* of National Taiwan University; work on leg 8 was in cooperation with the R/V ATLANTIS II of Woods Hole Oceanographic Institution.

INTRODUCTION

INDOPAC Expedition was a cooperative investigation of the deep circulation of the waters, and the nature of the crust beneath the sea floor, in the marginal basins of the western Pacific Ocean. Initial planning took place in 1973 at the Bangkok workshop, convened under the sponsorship of the CCOP (Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas), a U.N.-funded organization of East Asian states, and supported by the U.S. National Science Foundation Office of the International Decade of Ocean Exploration and by the Intergovernmental Oceanographic Commission of UNESCO. The Bangkok report proposed geophysical and geological studies of the convergent plate margins which dominate the tectonics of the southeast Asian offshore areas; it recommended concentration of efforts in strips crossing from sea to land: the Korean, Philippine, Banda, Sunda, Andaman, and Burma Transects. This, later named the "SEATAR" program (Studies of East Asia Tectonics and Resources), has provided a focus for geological and geophysical studies of active margins and the possible relationship of active margins to the origin of metal and petroleum deposits. Much of the work on Expedition INDOPAC has been supported by IDOE as part of the SEATAR program.

Legs 4, 5, and 6 of INDOPAC were all along the Philippine Transect. Leg 4 represents an initial stage of metallogenic studies supported by IDOE. Leg 5, carried out in cooperation with the Institute of Oceanography, National Taiwan University, Republic of China, provided preliminary site surveys for the International Program of Ocean Drilling series of drill sites across the marginal basins of the Philippine Sea. Leg 6, supported by the National Science Foundation and the Office of Naval Research, combined geology and physical oceanography in studies of the geological structures and turbidity currents in submarine canyons off the northwest coast of Luzon.

Legs 7 and 8 were in the Banda Transect. Leg 7, supported by NSF and ONR, was a preliminary study of the structures in the collision zone of the Molucca Sea and the water exchange between the Pacific and Indian Oceans through the eastern part of Indonesia. Leg 8 was a cooperative program with Woods Hole Oceanographic Institution and the Geological Survey of Indonesia, primarily supported by IDOE, with additional support from the Office of Naval Research (U.S.A.), the Geological Survey of Indonesia and the Bureau of Mineral Resources (Australia). It was a study of the structure of the Banda Sea collision zone and of the water properties in the deep closed basins of the Banda Sea and the Timor/Tanimbar/Aru/Ceram arcuate troughs.

INDOPAC Expedition is continuing. At the time of preparation of this report, the R/V THOMAS WASHINGTON has carried out a biological program and tests of a multichannel reflection system in the Challenger Deep near Guam, and then carried out a continuation of the geological and geophysical program in the Molucca Sea that was started on Leg 7. It will continue with geological and geophysical programs on the Andaman Transect, and then similar programs around Nias (near Sumatra) on the Sunda Transect. It will return through the Banda Sea to Honolulu, where programs of marine biology and physical oceanography will be carried out before the ship returns to San Diego in July, 1977.

Ancillary observations

In order to make full use of available time and facilities, additional "ancillary" observations are made from Scripps ships, whenever these do not conflict with the primary purpose of a cruise leg. When the WASHINGTON arrived at the site of a sampling or refraction receiving station, it had to slow to 3 knots for about 10 minutes while the reflection hydrophone streamer, airguns, and magnetometer were retrieved, before stopping. On leaving stations, it got underway at this speed while this same equipment was streamed. During each such period, a neuston tow was taken with a surface net streamed from the Daybrook crane on the starboard side. On stations, if marine life was noticed, dipnetting was carried out. One midwater trawl was made each leg. XBT drops were made in conjunction with each refraction station to provide information on water temperature used to compute the velocity of sound in water and thereby the range of the refraction shots. Echo sounding was carried out throughout the cruise, on two frequencies whenever possible. On leg 5, the 12-kHz echo sounder was operated without gating most of the time to follow the deep scattering layer. Magnetic and gravity measurements were recorded continually when the ship was underway. Weather observations were routinely made four times a day by the bridge watch.

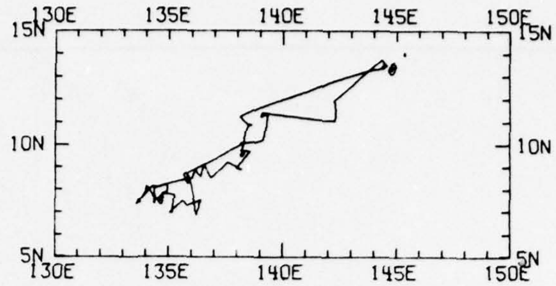


Fig. 1. Track chart of Leg 4.

INDOPAC LEG 4
CHIEF SCIENTIST: JAMES W. HAWKINS, JR.

The main objectives of INDOPAC, leg 4, were to survey the series of trenches and arcs between Guam and Palau, to sample the inner (western) walls of the trenches and to run reconnaissance survey lines and collect samples in the marginal basins which lie to the west of the arcs. These programs were designed to add useful information to the SEATAR project studies concerned with the evolution of island arcs and their role in metallogenesis. Trench wall samples were collected in order to understand the crustal composition of island arc "basement" in an area which appears to lack any continental material. The marine geological and geophysical studies were supplemented with land studies on Guam, the Yap Islands, and Koror and Babelthuap in the Palau group.

The R/V THOMAS WASHINGTON left Apra, Guam on 22 June and began a continuous underway survey program recording bathymetry, sediment thickness (using airgun seismic reflection profiling) magnetics and gravity. The south end of the Mariana Trench was surveyed and the complex intersection with the north end of the Yap Trench was crossed in several places to attempt to map the morphology of the zone of intersection. A dredge haul (D-1) in this zone of intersection gave serpentinized peridotite. Table I lists the dredge sites, locations, depths and rock types recovered.

The Yap Trench was sampled at three locations on the middle and upper parts of the western wall. A site at the northern end (D-2) yielded greenschists, which are similar to the schists exposed on the Yap Islands, and minor amounts of moderately fresh basalt fragments and porphyritic andesite. The dredge site (D-8) near shore off the northeast end of Gagil-Tomil, Yap Islands consisted largely of amphibolite schist, lime silicate gneiss and marble. The metamorphic rocks differ significantly from the schists which are the main rock types on Yap. Yap schists appear to be derived from ultramafic rocks, while the dredge 8 samples were derived from basaltic parent material and siliceous-calcareous shales and limestone. The mineral assemblages of the dredge 8 samples indicate amphibolite facies metamorphism (e.g., 450-550^{o}C and 3-4 Kb PH_2O): the Yap schists were last recrystallized under greenschist facies conditions (e.g., 300-350^{o}C and 2-3 Kb PH_2O). Some details of these studies were presented at the fall, 1976, meeting of the American Geophysical Union (Hawkins and Batiza, 1976) and a more extensive discussion is in manuscript form.

A third dredge site (D-7) in the Yap Trench sampled part of the slope of a "mid-slope basement high" area on the inner trench wall. The rocks are highly differentiated rocks of intermediate composition resembling hawaiite. They may represent fragments of a seamount which was plastered against the inner trench wall.

A varied collection of textural types of broadly andesitic composition rocks was dredged from the Palau Trench (D-5) close to the north end of Babelthuap. They appear to be closely similar to the Miocene andesites of the Palau Islands. A small seamount west of Babelthuap was dredged (D-6) but a thick cover of carbonate ooze prevented the recovery of any volcanic material.

In addition to the rock sampling activities, one gravity core was taken, two heat-flow stations were made, and the ship's track was planned to trace out structural trends. The bathymetry of the southwestern end of the Yap Arc has been slightly revised as a result of this survey and a preliminary version of the revision is included as Fig. 2.

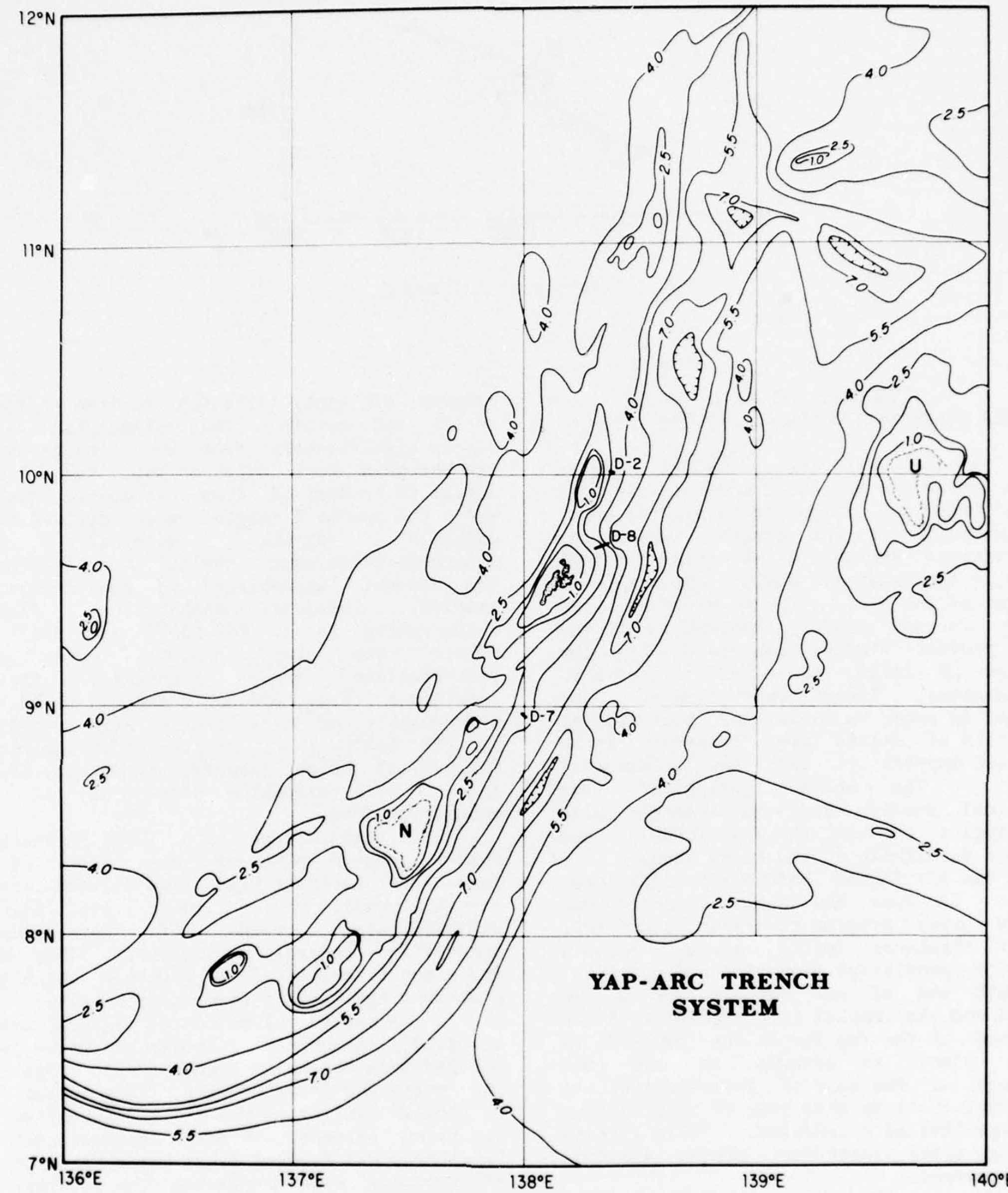


Fig. 2. Bathymetric sketch of Yap arc-trench system. Depths are in km. U = Ulithi, N = Ngulu, stippled area = Yap Islands. D-2, D-7, D-8 are locations of dredge sites.

Summary

Rock dredging of trench walls in the southwestern Pacific on INDOPAC leg 4 gave a variety of rock types. The Mariana Trench collection consists of serpentinized peridotite. The Yap Trench collection is quite anomalous and consists of greenschist, marble, amphibolite schist, basalt, andesite and "hawaiite". The Palau Trench samples are andesitic. The sampling indicates that the widely accepted simple model for trenches which envisions an accreted welt of clastic sedimentary material and sea floor sediments is not applicable to all trenches.

Chronology

June 22-23 R/V THOMAS WASHINGTON departed Apra Harbor, Guam on the evening of June 22 and began recording with magnetometer, gravimeter, 12- and 3.5-kHz echo sounders and the airgun reflection system. Recordings were continuous for the gravimeter during leg 4 and for the other systems whenever the ship was not on station.

The ship proceeded to the southern end of the Mariana Trough and passed over the Challenger Deep.

June 24-25 A westward course was taken from the Challenger Deep to the northern end of the Yap Trench, where the first dredge station was taken on the northern edge of the trench shortly after getting out of very shallow water. Later the second dredge station was taken northwest of the Yap Islands. Two XBTs were taken on June 25.

June 26 The first gravity core, heat flow and an XBT and later dredge station three were taken east of the northern end of the Palau Trough.

June 27 A neuston tow, XBT and dredge station four were taken south of the southern end of the Yap Trench.

June 28 Crossed the Palau Trough and took two XBTs and dredge station five on the western slope of the trough. The magnetometer was damaged in bringing it aboard on reaching the station and the magnetometer cable was replaced.

June 29 Took an XBT, dredge station six, a heat flow and neuston tow west of the Palau Islands.

There was difficulty with the 3.5-kHz echo sounder and it was secured from 1438Z, 29 June to 0158Z, 2 July.

June 29-30 Entered Kabasang Harbor, Koror, Palau Islands for medical attention for the Third Mate and left after a successful visit to the doctor. Crossed the Palau Trough and headed back to the Yap Trench.

July 1 Took dredge station seven and an XBT in the central section of the Yap Trench.

July 2-4 Took dredge station eight and an XBT just north of the Yap Islands July 2, and dredge station nine on the east side of the Yap Trench between dredge stations 1 and 2, and took an XBT July 3. The ship headed for Apra Harbor, Guam after leaving station nine and arrived there late on July 4 (GCT; morning of July 5, local time).

TABLE I

Rock dredge summary

INDOPAC, Leg 4

Dredge number	Latitude	Longitude	Depth range (meters)	Rock Types
1	11°15.4'N 11°15.8'N	139°21.0'E 139°20.3'E	2350 1566	Serpentinized peridotite
2	10°01.8'N 9°44.6'N	138°23.0'E 137°48.3'E	4028 1492	Greenschist, vesicular basalt, diabase, breccia, coral fragments
3	8°32.9'N 8°32.4'N	135°52.3'E 135°53.2'E	2742 2742	Buff-colored volcanic breccia, vesicular basalt
4	7°27.3'N 7°27.4'N	136°24.4'E 136°24.2'E	3555 3555	Mn-crusted yellow-tan volcanic breccia
5	7°46.7'N 7°47.6'N	134°46.7'E 134°45.3'E	4161 2686	Andesite breccia, porphyritic andesite, aphanitic andesite
6	7°26.1'N 7°29.3'N	133°43.0'E 133°45.9'E	3914 2723	Calcareous mud, foram-rich pumice
7	8°56.8'N 8°57.0'N	138°01.3'E 137°59.5'E	4546 3593	"Hawaiite", intermediate composition volcanic rocks, prehnite-laumontite veined volcanic rocks
8	9°40.6'N 9°40.8'N	138°20.5'E 138°17.5'E	3895 2704	Greenschist, amphibolite marble, lime-silicate gneiss
9	10°48.9'N 10°49.5'N	138°36.1'E 138°31.4'E	4900 3275	No recovery

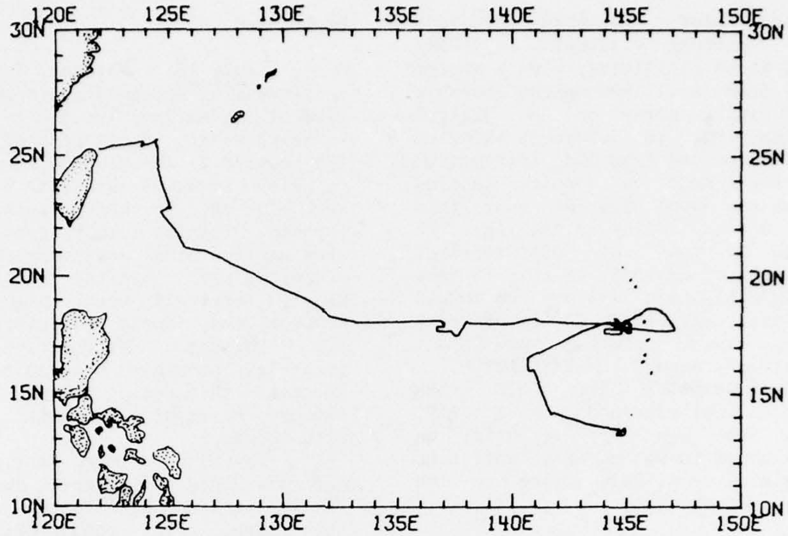


Fig. 3. Track chart of leg 5.

INDOPAC LEG 5
CHIEF SCIENTIST: GEORGE G. SHOR, JR.

Several projects were planned for this cruise leg. The primary program was a study of the variability of the structure of the oceanic crust in the marginal basins of the Philippine Sea. To make this study, two-ship seismic refraction stations were planned for the Marianas Trough, the Parece Vela Basin, and the West Philippine Basin, to determine whether the structure under these basins differed significantly from that of the "normal" Pacific Plate, and whether the basins themselves differed individually. While typhoon conditions reduced the planned number of stations in the Mariana Trough and in the Parece Vela Basin, sufficient data were obtained to show the main characteristics of the individual basins. The Mariana Trough has many of the characteristics of a spreading center. In addition to the high heat flow and geomorphology known in advance, it has relatively thin crust and low mantle velocity, similar to the East Pacific Rise. The Parece Vela Basin generally shows thickened "layer 2" basement, and thinner "oceanic crust" than a normal Pacific station. In the West Philippine Basin, some stations were found that had virtually no material with normal "layer 2" velocities.

A second program involved was the test of a horizontal array of hydrophones for refraction reception, to try to determine both the relative energy transmitted through the sea floor, and the direction of arrival of the fairly large fraction of the total refraction arrival that is not associated with discrete "energy packets" that can be explained by ray theory. On the stations where useful records were obtained by the array receivers, it was apparent that while coherent arrivals can be followed from one hydrophone to the next (at a 500-meter spacing) for the stronger packets of energy, the background has poor coherence at this spacing. A closer spacing was used for later tests on leg 8, with greater trace-to-trace coherence.

A brief study of the Okinawa Trough showed that this peculiar structure, which has many of the characteristics of a spreading center, has crust beneath it with thickness approaching normal continental.

Chronology

July 5 The R/V THOMAS WASHINGTON of Scripps Institution of Oceanography and the R/V CHIU LIEN of National Taiwan University rendezvoused at the U.S. Naval Base, Guam, Marianas, to prepare for two-ship operations across the Mariana Transect of the IPOD program, which is also the Luzon Transect of the IOC/IDOE/CCOP SEATAR program. Standard cable-connected AX-58 hydrophones and analog amplifiers, plus receiving equipment for use of Navy sonobuoys, were installed aboard CHIU LIEN by Scripps personnel; CHIU LIEN already had facilities for airgun and sparker

operation, and for receiving Select International sonobuoy signals. THOMAS WASHINGTON had these facilities, plus a system for recording from a 12-hydrophone towable refraction receiving array on a digital recording system. Due to delays in shipping of explosives requested from ONR, last-minute arrangements were made to acquire surplus explosives from the Naval Magazine, Guam; this resulted in a one-day delay in sailing. The ships received 20 tons of M034 tetratol charges, manufactured in 1945; of this 13 tons was taken by CHIU LIEN and 7 tons by THOMAS WASHINGTON. Other explosives for later work, plus necessary caps, primers, and small charges were already aboard the WASHINGTON.

THOMAS WASHINGTON and CHIU LIEN departed Guam on the afternoon of 8 July, 1976. George Shor was chief scientist on WASHINGTON; Richard Lu was chief scientist on CHIU LIEN, assisted by L. Dale Bibee to run the refraction program.

July 9 was spent in the southern part of the Parece Vela Basin (south of the line of IPOD sites) testing equipment. There was trouble with the intership radio system, and the end of the refraction receiving array was accidentally cut off but was recovered. A neuston tow was made at this site, and the two ships proceeded on parallel courses overnight; WASHINGTON made airgun runs to the 9 July station and on to the 10 July site for the first refraction station.

July 10 - Parece Vela Basin. WASHINGTON could hear CHIU LIEN on the radio, but not vice versa, so CHIU LIEN shot on a fixed schedule. WASHINGTON received on the first three units of the refraction array, lying to, while CHIU LIEN shot a one-way refraction run. A heat-flow measurement and a neuston tow were taken at this site by WASHINGTON. Usable refraction arrivals were obtained out to 48 km, and a rough layer solution (without topographic corrections) gives:

	Velocity	Thickness
Water	1.5	4.8
Sediment	2.0	0.7
Basement	6.2	2.4
Crust	7.1	3.8
Mantle	8.3	

July 11 - WASHINGTON ran airgun, 12-kHz and 3.5-kHz soundings, magnetometer, gravimeter and took one neuston tow; CHIU LIEN used sparker system for reflection work. Started grid survey of Mariana Trough around axial high at 18°N; worsening weather due to the approach of Typhoon Therese caused us to cancel the last part of the planned survey to begin refraction work. CHIU LIEN sparker broke down.

July 12 - Mariana Trough. CHIU LIEN received with streamed hydrophones on the east side of the Mariana Trough, on the edge of the sediment wedge, just east of the axial high, for station 2. WASHINGTON received on station 3, which reverses station 2. Noise levels were high due to heavy seas caused by the typhoon. Initial results from these stations show upper crustal structure similar to normal oceanic, with typical oceanic thickness. Mantle arrivals were highly attenuated, however, and mantle velocity was low (about 7.6 km/sec). Travel-time curves were irregular probably because of variations of sediment thickness, making it difficult to measure basement velocities or thicknesses with accuracy.

WASHINGTON moved west after station 3, and relaunched hydrophones over the ridge to receive station 4; CHIU LIEN shot north along the ridge. The topography was extremely rough, and records were getting noisier because of high waves. CHIU LIEN then received station 5, reverse of 4, while WASHINGTON shot. The data show essentially the same structure as stations 2 and 3, with low velocity mantle.

July 13 - Mariana Trough. CHIU LIEN moved west again to receive station 6, on the west side of the high; WASHINGTON shot to the south. Results were similar to those on stations 2/3 and 4/5. Weather reports at this point indicated that Typhoon Therese, which had earlier been moving west along a line to the south of us, had changed course, and was heading north directly toward us. We canceled the reversal of this line, and WASHINGTON headed east to avoid the storm. CHIU LIEN, which was slightly to the west, headed west, crossing the front of the typhoon (within 60 miles of the center) and experienced 80-knot winds and rough seas. Minor damage was done to their airgun winch, and a spar was driven through the storage box for hydrophone cables, damaging one cable. Only two hydrophones were used from then on. CHIU LIEN also had damage to radio antennae, which temporarily ended communications between the ships. WASHINGTON went east past the north side of Pagan Island. Because of heavy surge, airgun streamer and magnetometer were brought in to avoid risk of catching them under the ship, and only the echo sounders were used on this run.

July 14 was spent east of Pagan Island, riding out the typhoon and trying to reestablish contact between ships. WASHINGTON came back west, south of Pagan Island, behind the typhoon, and reestablished contact with CHIU LIEN in the Parece Vela Basin late on the 15th at station 7 (IPOD Site SP5).

July 15 - Parece Vela Basin - started stations 7 and 8. WASHINGTON dropped 3 sonobuoys, shot a run (station 7) which is outgoing from the sonobuoys, incoming to the CHIU LIEN. Run 8 was then shot outward west from CHIU LIEN. CHIU LIEN shot an inbound run (run 9) west to the WASHINGTON. Mantle arrivals were observed on all three runs. WASHINGTON took a piston core, and a neuston tow.

July 17 - Western Parece Vela Basin. While this area is still in the Parece Vela Basin according to the charts, it probably should have a different name; the topography is distinctly rougher than the eastern portion. En route CHIU LIEN dropped a set of SSQ-41A sonobuoys and shot a short one-way station (10). Then WASHINGTON streamed 9 units of its refraction array to receive station 11 and towed the system outward from CHIU LIEN. Eight of the 9 units worked, and CHIU LIEN shot 13 shots (120-1b each) over a period of 6 hours. Because of previous problems, CHIU LIEN stayed well away from the end of the array; on this station they were 5 km from the end of the array for the first shot, beyond the cross-over range. Between shots, CHIU LIEN steamed into the wind at about 2 knots, then turned and ran at full speed for 5 minutes to drop the shots. The WASHINGTON towed the array at 5 knots, stopping 5 minutes before shot time to let the array quiet, and getting underway 2 minutes after the shot was dropped. Data were recorded digitally; hydrophones were spaced 500 meters apart. Noise levels were higher than on the normal streamed hydrophones. Unfortunately, the location (IPOD Site 6a) is not suitable for refraction work. A deep trough was crossed during the run, which makes topographic corrections dubious. This trough was about 7000 meters deep, and is in line with the extension of the Yap Trench, as are a number of other deep soundings noted on the chart. It is quite probable that there is a semicontinuous deep, filled in places, extending north from the presently known end of the Yap Trench. If so, the rough area from here west should not be included under the same name as the smoothly sedimented Parece Vela Basin to the east. On a record-section playback of the data, there are strong arrivals with velocity 6.8 to 7.0 km/sec, no indications of a basement arrival even as second arrivals, and mantle arrivals doubtful or absent.

July 18 - Western Parece Vela Basin. Made a standard reversed profile, on a course to the southwest to try to stay with the grain of the topography (as shown on the chart). CHIU LIEN received station 12, WASHINGTON shot. Just south of the receiving position, the WASHINGTON crossed a plateau 300 fathoms shallower than prevailing depth. CHIU LIEN then shot station 13 to the WASHINGTON. The crustal velocity is low (about 6.6 km/sec). Usable mantle arrivals were recorded on station 12, but not on 13.

July 19 - Western Parece Vela Basin. WASHINGTON received, while CHIU LIEN shot three short lines north, south, and east of station, and then a long run west, for runs 14, 15, 16, and 17. Station 15 shows about 2 km of 4.8 km/sec material overlying 7.1 km/sec material. Station 16 shows 2 km of 4.5 km/sec over 7.0 km/sec. Station 17 shows mantle arrivals with high apparent velocity (about 9.2 km/sec) at 30 km range. This station was not reversed; time was short, and we were moving west to get clear of another typhoon.

July 20 - West Philippine Basin. CHIU LIEN received an incoming run (station 18) and outgoing (station 19) for a split. WASHINGTON then received 20 (incoming) and 21 (outgoing), the two splits overlapping for a reversed pair. WASHINGTON took a piston core, heat flow, and neuston tow. All four runs show mantle cross-over at about D=15 to 20 seconds, 6.7 to 7.0 km/sec crustal velocity, normal mantle velocity.

July 21 - West Philippine Basin. WASHINGTON put out the long array again, with 11 units out. CHIU LIEN started shooting, but noise levels were very high even compared to large shots at close range. At this point two supertankers appeared on the horizon, and we pulled in the system rather than risk the array. This represents two short runs, stations 22 and 23. Took heatflow number 7.

July 22 Another storm behind us, underway all day, routine underway geophysics.

July 23 - West Philippine Basin. WASHINGTON dropped 3 sonobuoys, shot from them to the CHIU LIEN (station 24) and outward (station 25) for a reverse and split. WASHINGTON then stopped on station, took heat flow (unsuccessful; instrument failed to record), gravity core (1 foot), and 3 neuston tows. Then received an incoming run (station 26). Preliminary analysis of station 25 indicates low crustal velocity (about 6.1 km/sec) going directly to mantle (about 8.2 km/sec).

July 24 - West Philippine Basin. CHIU LIEN shot a run to a Select International low-frequency sonobuoy, with good radio range out to D=45 sec (27). WASHINGTON tried an unsuccessful heat-flow lowering. WASHINGTON picked up the buoy that CHIU LIEN put out, and both ships proceeded across the Ryukyu Trench

and Ridge.

July 25 - Okinawa Trough. Crossed a deeply filled graben in the Okinawa Trough; WASHINGTON returned to the center of the graben and put out its receiving array, lay to, and received on 4 units. *CHIU LIEN* shot short runs east and north (stations 28 and 29), then a long run (30) to the west.

July 26 - Okinawa Trough. CHIU LIEN returned to the WASHINGTON receiving position; WASHINGTON moved west and received station 31 (reverse of 30), and 32 (split with 31). Station 30 was digitized. Preliminary calculation shows mantle depth intermediate between oceanic and continental beneath the Okinawa Trough. Took a midwater trawl, a heat flow and core, and headed to Keelung, arriving on the morning of 27 July.

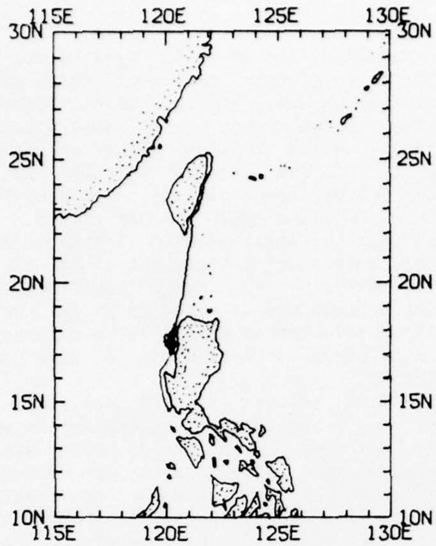


Fig. 4. Track chart of leg 6.

INDOPAC LEG 6
CHIEF SCIENTIST: FRANCIS P. SHEPARD

This leg started with the running of a line of soundings and seismic profiles down along the submarine fault scarp on the east side of Taiwan. We discovered a new fault trough somewhat south of the previously known Okinawa Trough that runs into the land near the northern tip of the island. Many deep submarine canyons were indicated along the fault scarp.

The main purpose of leg 6 was to investigate the currents in submarine canyons on the slope off the Abra Delta in northwest Luzon. Our current meters recorded what we consider to be a turbidity current that shows a great contrast to the ordinary canyon currents. We have now seen the same type of current in records off La Jolla and in the valley off the Rio Balsas Delta in western Mexico. These are virtually the first complete records of turbidity currents in existence (one other off the Var River in southern France). It is significant that we have found indications of turbidity currents in the delta-front valleys in both areas where we have used current meters. On the other hand our numerous records in the canyons of many other areas have yielded only one example. This suggests that turbidity currents are much more common in these delta-front valleys than elsewhere.

We made a very extensive survey of the sea floor in the vicinity of the Abra Delta and discovered what appears to be a northward continuation of the great Philippine Fault which leaves the coast of Luzon in this area. Numerous seismic profiles show how the fault continues with large displacement and extends down the slope into the South China Sea. One profile shows the usual depression at the base of a fault scarp.

The survey off the Abra Delta and vicinity has been contoured at a 100-m interval. The map shows that the valleys extend down the submarine slope of the delta and upon reaching a trough that is related to the faulting of the area can be traced seaward, with the southern valleys draining south into a submarine canyon that extends seaward to at least 2,000 m, whereas the central and northern valleys extending along the trough to the north continue down to 2,900 m in a rift valley that reaches the base of the slope in the Manila Trench and forms a depression along the east margin of the Trench.

Chronology

July 31-August 1 WASHINGTON left Keelung harbor in the forenoon of July 31 and started recording with gravimeter, magnetometer, 12- and 3.5-kHz GDR, and the airgun reflection system. The 12-kHz GDR was not gated during most of this leg so that there would be a record of the deep scattering layer as well as the 3.5-kHz GDR record of bathymetry. While steaming down the steep submarine fault scarp on the east side of Taiwan, numerous submarine canyons were crossed. A neuston tow was taken on July 31 shortly after leaving Keelung harbor.

August 2 The WASHINGTON continued south toward Luzon, passing over the North Luzon Trough. On reaching the Abra River Delta on the west coast of northern Luzon Island, two current meters were set in the canyon directly off the Abra River mouth and a neuston tow was taken. A midwater trawl and a second neuston tow were taken later in the day.

August 3-10 An extensive bathymetric and reflection survey of the Abra River Delta was made close inshore. Twenty-three gravity cores were taken in the canyons, obtaining samples ranging from soft sediment to gravel. The first current meter setting was retrieved and a second setting was made and retrieved. On August 7, 9, and 10 wide-angle reflection profiles were taken using sonobuoys and airguns. Twelve neuston tows were taken during this period.

August 11 Having completed the Abra Delta survey, the WASHINGTON continued to Subic Bay, Philippine Sea Islands taking a neuston tow in the channel just before entering harbor.

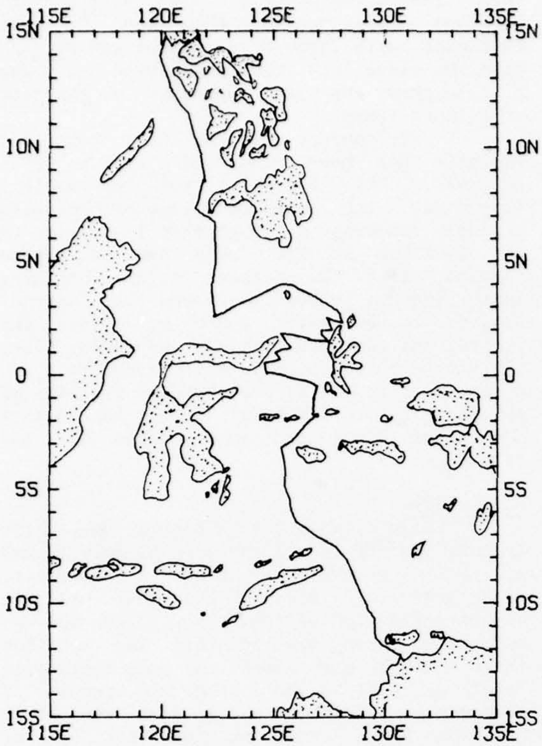


Fig. 5. Track chart of leg 7.

INDOPAC LEG 7
CO-CHIEF SCIENTISTS:
ELI SILVER AND WILLIAM PATZERT

The purpose of the geophysical studies on leg 7, directed by Eli Silver, was to examine the structure of the collision zone between the Sangihe and Halmahera island arcs. For this study seismic reflection data and gravity proved to be the most useful tools.

The seismic reflection profiles showed that the central region of the Molucca Sea is composed of highly deformed material which is in thrust contact with the arc aprons on either side. The thrust faults are marked topographically by troughs which are about 1 km deeper than the average water depth in the Molucca Sea. The seismic profiles show the surprising result that the deformed material seaward of each arc is thrusting over the arc along low angle thrusts. We can follow structurally coherent sediments of the arc front below the deformed, incoherent material of the collision zone horizontally for up to 15 km and vertically to 3 km.

Gravity anomalies in the Molucca Sea reach values as low as -250 mgal free air. Such intense gravity minima are found almost exclusively in areas of deep oceanic trenches. Here the minima occur over water depths of only 2 km, which implies either an enormous thickness of low density material in the Molucca Sea or, less likely, anomalously low density crust and upper mantle rocks. The gravity can be explained with a rather simple crustal model containing about 10 km of low density material in the Molucca Sea. The contact between the deformed rocks and the arc is a low angle thrust within 25 km adjacent to the arc, then steepens to a high angle contact.

The structure of this collision zone illustrates a significant mechanism by which highly deformed or melanged belts can be emplaced up onto island arcs or convergent continental margins yet down a gravitational gradient. The central part of the Molucca Sea deformed zone reaches sea level at islands along the Talaud-Mayu ridge, whereas the troughs marking the zones of thrusting are at depths of about 3 km. Thus the deformed melange material moves downslope away from the central high but thrusts up over the arcs.

During INDOPAC legs 7 and 8 an ONR-supported program of hydrographic and current measurements was carried out by William Patzert along the cruise track. Twelve deep hydrographic casts were obtained on leg 7; 7 more casts were made on leg 8. Two current meter deployments were made in the Lifamatola Straits during leg 7 and recovered at the end of leg 8, yielding five-week records. The hydrographic data obtained include temperature, salinity, oxygen, and nutrient content. These observations were coordinated with a similar traverse one month earlier aboard the R/V VEMA of Lamont-Doherty Geological Observatory, on which six of the same station locations had been occupied and various supplementary chemical and radioisotope measurements collected. These included pCO_2, ΣCO_2, C^{14}, Ra^{228}, and Rn^{222}.

Initial analysis of the various data sets indicates that these basins are being flushed rapidly. Almost neutral stability vertically, weak vertical gradients and high values of oxygen to depths as great as 5000 m, and young, well-mixed waters (indicated by the C^{14} and Ra^{226} measurements) all tend towards the following conclusions: The basins show almost no geothermal heating, radiocarbon decay, respiration effects, silica dissolution or Ra^{226} input: they are strongly ventilated. The steady, strong currents (~25 cm/sec) at 2000 m depth observed over the Lifamatola Sill are certainly consistent with the fast flushing--with the sense of exchange from the Pacific to the Indian Ocean.

Chronology

August 14-19 R/V THOMAS WASHINGTON departed Subic Bay, Philippine Islands with Dr. Eli Silver, UCSC, and Dr. William Patzert, SIO, as co-chief scientists 14 August to do a preliminary geophysical and hydrographic survey of the Molucca Sea. Recording was started with gravimeter, magnetometer, 3.5-kHz GDR and the airgun reflection system. This recording was continuous during leg 7 for the gravimeter and was interrupted for the other systems only at hydrographic stations, the dredge station and during a brief stop at Zamboanga, Mindanao, to disembark Lt. Galera of the Philippine Coast Guard. The 12-kHz GDR did not work well at the beginning of the leg, with a record from 2334Z August 15 to August 16. However it was repaired and 12-kHz records are continuous from 0705Z August 18 for the rest of the cruise except when we were on station. A strong earthquake was felt aboard ship the night of August 16 before entering Zamboanga harbor. Neuston tows, hydrocasts, and STD lowerings were taken August 16 in the Sulu Basin, August 18 in the Celebes Basin and a hydrographic cast and STD lowering were taken August 19 in the Sangihe Basin.

August 20-24 The WASHINGTON continued the intensive reflection survey in the Molucca Sea zigzagging west of Halmahera Island, crossing the Molucca Sea and zigzagging east of the eastward extension of Sulawesi, where a rock dredge was taken August 22. A second Molucca Sea crossing was made August 24 and shortly afterward the ship headed south. This concluded the most intensive section of reflection surveying although standard reflection work was continued for the entire leg. Neuston tows, hydrocasts and STD lowerings were taken on the 20th in the Morotai Basin, the 21st in the Talaud Trough, the 23rd in the Gorontalo Basin and the 24th in the Batjan Basin.

August 24-25 Three current meters were moored in the deep channel through Lifamatola Strait connecting the Molucca and Banda Seas, to be picked up on leg 8. A neuston tow, hydrocast and STD lowering were done as soon as the moorings were set. Another neuston tow, hydrocast and STD lowering were made about 12 hours later in the North Banda Basin.

August 26 A midwater trawl was taken between the North and South Banda Basins.

August 26-27 A neuston tow, hydrocast and STD lowering were taken in the South Banda Basin and another hydrocast and STD lowering were taken at the southern edge of the South Banda Basin.

August 28 A neuston tow, hydrocast and STD lowering were taken in the Timor Trough; the WASHINGTON then headed toward port.

August 29 Arrived in port, Darwin, N.T., Australia.

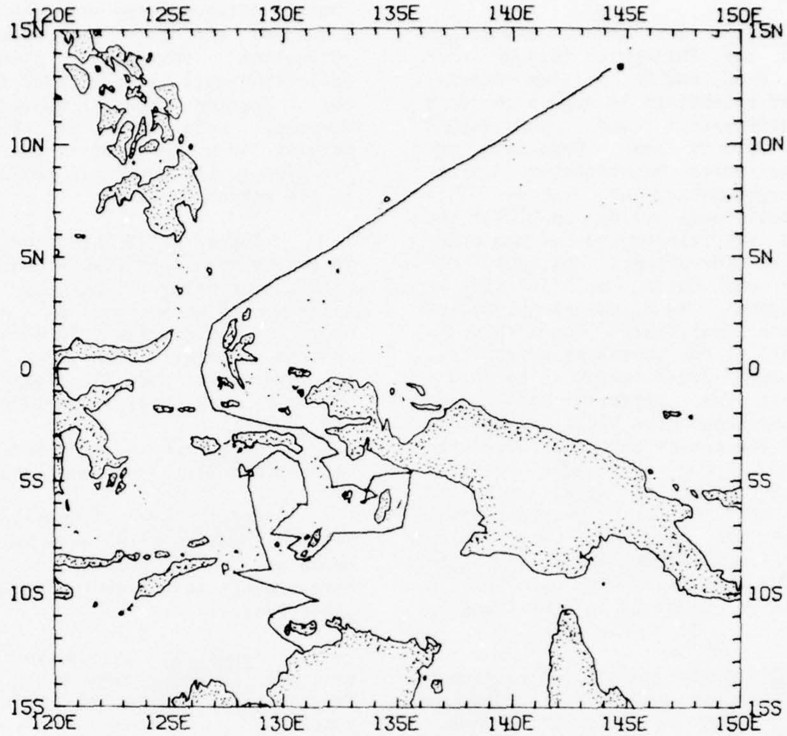


Fig. 6. Track chart of leg 8.

INDOPAC LEG 8
CHIEF SCIENTIST: GEORGE G. SHOR, JR.

The immediate purpose of the geological and geophysical program carried out on INDOPAC 8 was to obtain an understanding of the structure and history of the Banda Sea, the Banda Arc, and the Sahul Shelf in the zone of collision of the Australian Plate with the complex zone of plates and platelets to the north. To obtain this understanding, we carried out an extensive program of two-ship seismic refraction stations within the Banda Sea, around the Banda Arc, and in selected locations in the Timor-Tanimbar-Aru Trough complex and on the continental shelf of the Sahul Shelf. Gravity, magnetics, heat flow, reflection profiling, and echo sounding were important programs, but during the period of two-ship operations were subordinated to the two-ship refraction work. Additional work was done on the other programs by the ATLANTIS II in the month following the departure of the THOMAS WASHINGTON. Reconnaissance studies of key islands in the area were done by geologists who were placed ashore by the Indonesian ship KELAPA, which also emplaced portable seismograph stations (provided by ANU) on the islands.

Preliminary analysis shows that the Sahul Shelf is a "typical" continental mass in the area close to Melville Island, off northern Australia. Continental structure is also found beneath the Timor-Tanimbar-Aru Trough complex, where it would not necessarily be expected, with similar thickness of continental crust to that under the southern part of the shelf. The interior basins of the Banda Sea, including the 7-km-deep Weber Deep, have structure that approximate that of "normal" oceanic crust; there may be some significant but small differences. No areas of extreme heat flow were found. The general structure can perhaps be explained as a collision process that is in transition between a normal subduction of oceanic crust under an island arc (with the oceanic crust, formerly located north of Timor, now completely subducted) and a Himalaya-type collision between the Australian continent and the island-arc and continental fragments of offshore southeast Asia.

Chronology

August 29 The R/V THOMAS WASHINGTON met the R/V ATLANTIS II of Woods Hole Oceanographic Institution in Darwin, Northern Territory, Australia, to prepare for two-ship operations on the Banda Transect. Some equipment and personnel was exchanged between ships, and final plans were made. ATLANTIS II received explosives (TNC) supplied by the Australian Bureau of Mineral Resources; WASHINGTON already had aboard explosives provided by the Office of Naval Research. The two ships left Darwin on the afternoon of 2 September, to proceed to the first station.

September 3 Sahul Shelf. ATLANTIS II set an ocean bottom seismometer southwest of the proposed starting position of the first station, to be recovered later. WASHINGTON stopped north of Melville Island, over a 40-fathom depression. ATLANTIS II shot a line outward to the northeast. Water-wave arrivals (necessary for measuring shot to receiver range) faded out at about 55 km; ranges were computed from satellite navigation fixes on both ships. Acoustic noise levels were extremely low (in part because of very calm weather and in part because of topographic shielding from water-transmitted noise), so that the analog amplifiers for the WASHINGTON refraction system could be operated at full gain. Usable refraction signals were obtained out to a range of 224 km. ALTANTIS II then stopped to receive station 2, using modified Select International 73 mHz sonobuoys. They received water waves to a range of 105 km. A preliminary solution for station 1 gives:

Water	1.54 km/sec	.077 km
Sediment	2.09 km/sec	1.37 km
Basement?	5.85 km/sec	8.6 km
Crust	6.49 km/sec	27.0 km
Mantle	8.34 km/sec	

Total depth to mantle: 37 km. The solution is subject to modification when the reverse data from station 2 is combined with it. Other observations 2/3 September: gravity (continuous); magnetics (except during station); 3.5- and 12-kHz echo sounding; one neuston tow; one XBT.

September 4 Underway to Timor Trough. WASHINGTON operating airgun, magnetometer, gravimeter, 12- and 3.5-kHz echo sounder. The airgun record shows sediments dipping down into the Timor Trough, interrupted by numerous small faults, most of which show down-dropping towards the trough. A small wedge of flat-lying sediments occupies the bottom of the trough, and reflections from the deeper, dipping sediments can be seen beneath the north "wall" of the trough. At this location they show an apparent upward tilt on the time section; this will probably change to a true downward dip when the section is converted to depth rather than reflection time. WASHINGTON went part way up the north slope of the trough, then turned and came to the center of the trough where ATLANTIS II was ready to receive refraction station 3. Other observations: neuston tow.

September 5-6 Timor Trough. WASHINGTON shot refraction station 3 along the Timor Trough, trying to stay within the trough. Several times the water shoaled, and we changed course to the south to come back into the trough, then resumed base course and continued shooting. Near the end of the run the water shoaled and turning did not bring deeper water; apparently we came up onto a shoaler portion of the trough. The reflection profiler was operated during the shooting run, using a single airgun (streamed from the side opposite the shooting table), and an EVP-23 streamer to avoid chance of damage to the newer streamers which are less easily repaired. At times side echoes from the north wall were superimposed on the reflection record of the trough floor. At completion of the station, WASHINGTON stopped to receive station 4. The hydrophone array was streamed for this station, with the ship lying to. The array consisted of 10 separately streamed hydrophones, each attached to a telemetry unit on a NOLARO rope strain member. Signals were transmitted by radio (using sonobuoy transmitters) from 8 telemetry units to the ship; the nearest two units sent signals by wire up the strain line. One of the units failed to work; three others were noisy at various times, so that the number of useful receiving channels varied between 6 and 9. The system streamed in a direction nearly along the shooting line. The ship held position with the bow thruster between shots, in order to maintain the array as straight as possible. There were some problems of radio communications between ships, which were cured. Our primary frequency, usable in other areas, turned out to be too close to the calling frequency for the Darwin radiotelephone station, and there were problems in one transceiver on the secondary intership frequency. The refraction station showed normal continental crustal velocities, and a thick (continental) crust, confirming results of the shorter station at the same location taken in 1960 on Expedition MONSOON. Noise levels were not as low as on station 1, but not unusually high.

While on station 4, WASHINGTON made a heat-flow measurement (which gave low heat flow), a gravity core, a STD lowering, an XBT, neuston tow, and a deep and shallow hydrographic cast. The weather was calm, and much sea life (including fish, jellyfish, and one basking shark) surrounded the ship during

the station.

September 7 Banda Sea. WASHINGTON made a reflection run north across the Banda Sea, operating airgun profiler, magnetometer, gravimeter, 12- and 3.5-kHz echo-sounder system.

September 8 Banda Sea. Refraction station 5 was planned for the top of a ridge south of Ceram; WASHINGTON spent the night of the 7th-8th surveying to find the ridge. It seems to be discontinuous, and had been only based on widely spaced sounding lines. WASHINGTON stopped to receive refraction station 5 in a deep area over a sediment-filled valley. This station was received on a standard 3-hydrophone set, plus two units of the array system, while we experimented with methods of quieting the array. While we were surveying, the ATLANTIS II rendezvoused with the M/V KELAPA, which transported island seismometers to their sites, and geological staff for island studies. ATLANTIS II shot to us, then out beyond to the northeast for a "split profile." On the outgoing run, they crossed over a shoal area that had not been found in our pre-station survey, then down into deep water on the far side. This rough topography makes some of the refraction data unusable, but enough is unaffected to show that the structure approximates a normal deep-sea station, with mantle at about 12 km depth. Refraction data were directly digitized through the PDP-8 system. A gravity core and a heat-flow measurement were taken at this station. One echo-sounder recorder broke down, so that we had to choose between using 3.5-kHz or 12-kHz echo sounding from here on. The 3.5-kHz system was operated between stations; the 12-kHz system on station in order to listen to pinger signals. One of the ship's main propulsion engines broke down, with a cracked cylinder liner. The ship therefore ran at reduced speed on one engine to the next station, while repairs were made.

September 9 Banda Sea (north of Weber Deep). ATLANTIS II stopped on a topographic bench on the northeast side of the trough that extends from the north end of the Weber Deep. WASHINGTON shot station 6 to the southeast at 8 knots on one engine. This was the beginning of a series of leapfrog stations in the Weber Basin from station 6 through station 11. WASHINGTON then received station 7, a reversal of 6, on 5 hydrophones: 3 standard hydrophones and 2 array units. A gravity core, an STD lowering, a hydrocast, neuston tow, and 2 XBTs were taken on station 7. The refraction results (preliminary shipboard solution) for station 7 showed crust similar to oceanic crust, but possibly not identical.

September 9-10 Weber Basin. WASHINGTON started shooting station 8 toward ATLANTIS II but suspended shooting as ATLANTIS II was having trouble with noisy hydrophones. WASHINGTON continued running toward ATLANTIS II and was able to resume shooting about 10 minutes before coming abeam. A neuston tow was taken at the start of the station. WASHINGTON continued shooting the outgoing run of station 8 beyond ATLANTIS II.

September 10 Weber Deep. WASHINGTON stopped on station 9 and took a gravity core, a deep hydrocast, and an STD lowering. The seismic station was delayed until the core was up and a heat flow had also been taken. It was windy with a rather rough sea. As the wind and currents were going in different directions it was difficult to hold station. Two neuston tows and an XBT were taken.

September 11-12 Weber Deep. After completing the heat flow, WASHINGTON lay to and streamed 3 standard hydrophones. There was a strong current pull and it was necessary to slack the phones to quiet them when the shot was due. Station 9 was a reversal of station 8 outgoing. Two XBTs were taken.

ATLANTIS II stopped at the end of station 9 to receive station 10. WASHINGTON was delayed in starting shooting as one cooling fan motor for the ship's propulsion motor was out. The WASHINGTON finally shot the run on one engine. It was necessary to fire the large charges with much longer fuses than usual so that the WASHINGTON would not be jarred too much at its slower speed. During the run there was strong radio interference.

WASHINGTON stopped at the end of station 10 to receive station 11. The incoming run of station 11 reversed the outgoing run of station 10. WASHINGTON put out 3 standard hydrophones and took a gravity core, a heat flow and a neuston tow and 2 XBTs. It was necessary to steam on station to hold vertical wire angle and to keep the hydrophones quiet.

The preliminary layer solution on refraction station 11 shows structure similar to normal oceanic.

September 13 After leaving station 11, the WASHINGTON ran a survey pattern northeast of Babar Island to Seroe Island with gravimeter, magnetometer, reflection profiling, and 3.5-kHz echo sounding, while ATLANTIS II surveyed along track farther to the west.

Arriving at the Tanimbar Saddle (between the Timor Trough and the Tanimbar Trough) the WASHINGTON stopped to receive

station 12. There was a short incoming run and then a long outgoing one toward the northeast end of the Tanimbar Trough.

There was some difficulty on this station with noisy hydrophones. On pulling them in at the end of the station it was found that the two distant phones were tangled together.

While receiving station 12, WASHINGTON also took a gravity core, heat flow, hydrocast, STD lowering and an XBT. One of the refraction hydrophones was caught and carried down with the hydrocast. The hydrophone float collapsed because of excessive pressure.

The outgoing run of station 12 is reversed by both stations 13 and 17.

September 14 Tanimbar Trough. WASHINGTON shot station 13 in to ATLANTIS II reversing station 12. Shortly after the first shot the airgun record stopped. We discovered that the airgun streamer had partially parted; we slowed the ship, brought in the streamer and repaired it before continuing the run. About three hours into the station the ATLANTIS II stopped recording temporarily to replace their sonobuoys with 2 new ones. WASHINGTON changed course and used the time to get back into the deepest part of the trough. Base course and shooting were resumed when we were back in the trough. A neuston tow and an XBT were taken.

The ATLANTIS II's Aquatronics buoy was monitored on the WASHINGTON in from about 35 km range. After completion of the station, the two ships proceeded in company to station 14, east of Aru Islands.

September 15-16 Sahul Shelf (east of Aru Island). A reversed pair of refraction stations were carried out on the continental shelf, east of Aru. Because of the shallow water, no magnetic or reflection observations were carried out during shooting. WASHINGTON shot station 14 out from ATLANTIS II. The water depth varied from 10 to 50 fathoms, so that very long fuses had to be used for the larger shots. The ATLANTIS II's Aquatronics sonobuoys were recorded out to 92 km range. The station ended about 10 miles south of the coast of West Irian where the WASHINGTON stopped to receive the next station.

ATLANTIS II shot station 15 to the WASHINGTON, reversing station 14. There was some difficulty with radio contact because of distance, so shooting was initiated on a fixed schedule. WASHINGTON did not receive firing marks for the first 7 hours of the run but was able to recover them from the ATLANTIS II records after the run by checking the electronic clocks on both ships.

While stopped on receiving station 15, WASHINGTON took a gravity core, 2 neuston tows and an XBT. Preliminary study of records of station 15 does not show arrivals from mantle. After the station, both ships proceeded to the Aru Basin; WASHINGTON operated reflection profiler, magnetometer, gravimeter, 3.5-kHz echo sounder.

September 17-18 Aru Basin. WASHINGTON started shooting station 16 as an outgoing run from ATLANTIS II but ATLANTIS II had difficulty with noisy sonobuoys and radio interference. After 9 hours of stops, starts and course reversals it was decided to discontinue the station and have the WASHINGTON go to the receiving position for station 17 at the south end of the Aru Basin. A neuston tow was taken.

ATLANTIS II shot the incoming run of station 17. While receiving it the WASHINGTON also took a gravity core, heat flow, a hydrocast, XBT, neuston tow, and an STD lowering. As the wind varied from 10 to 17 knots the WASHINGTON steamed on station to slack the hydrophone cables.

When ATLANTIS II came abeam they stopped and hydrophones, cables, an amplifier and Paul O'Neill were transferred from WASHINGTON. After the transfer ATLANTIS II resumed shooting with a long outgoing run from the Aru Basin southwest along the Tanimbar Trough. The far end of this run reached the location of station 13; stations 12, 13, and 17 are therefore being worked up as a set. The preliminary solution for 12 and 17 as a reversed pair shows deep mantle (ca. 40 km), continental crustal velocity, and about 3.5 km of material with velocity 5 km/sec that could be either basement or a high-velocity carbonate section.

After finishing station 17 the ATLANTIS II ran a reflection survey west of the Kai Islands and visited Kur Island. The WASHINGTON ran an airgun survey across the Aru Basin northeast to Aru Island and then west to Great Kai using two large airguns as well as magnetometer, gravimeter and 3.5-kHz echo sounding. After crossing the Aru Basin the second time, WASHINGTON slowed and took a midwater trawl, neuston tow and XBT.

September 20 Ridge southeast of Ceram, outer Banda Arc. WASHINGTON arrived at the receiving position for station 18, east of Kur Island, took two gravity cores, a hydrocast and an STD lowering, a neuston tow and 2 XBTs. ATLANTIS II shot a very short incoming run and then a short outgoing one for station 18. Then ATLANTIS II stopped to receive station 19 using an OBH, Aquatronics sonobuoys and streamed hydrophones. Station 19 was shot by the WASHINGTON to and beyond ATLANTIS II. WASHINGTON monitored the ATLANTIS II's sonobuoys through the station. Seismic signal strength was very poor on both

runs, and crustal arrivals were never received. Apparently the low-velocity material forming the ridge has very high absorption.

September 21 Ridge southeast of Ceram, outer Banda Arc. ATLANTIS II shot station 20 in to the WASHINGTON to reverse the north side of station 19. Records were very poor due to the high absorption.

After the station both ships moved on to the Ceram Trough on parallel tracks, carrying out underway geophysical work. The gravimeter showed abnormal readings on this run, with a 5-minute square wave; cause not immediately determined.

September 21-22 Ceram Trough. On reaching the receiving position for station 21 the WASHINGTON did a hydrocast and STD lowering, a gravity core, heat flow, neuston tow, and XBT and received the incoming run. The receiving position for station 21 was in a water depth of about 1200 fms over flat-lying sediments of at least 0.5 sec thickness overlying deep basement.

Station 22 was a split, shot by the WASHINGTON. While shooting the run they also recorded one 300 in^3 airgun. There was some difficulty staying in the trough on the incoming run. ATLANTIS II drifted out and had to move back in. WASHINGTON lost the trough, turned north but couldn't find it again until they turned back toward ATLANTIS II; the trough may be discontinuous here. The first half of station 22 showed about the same depth of sediment as the receiving position on station 21, but it was no longer flat-lying.

When the ships came abeam there was a boat transfer, Paul O'Neill returning to the WASHINGTON. The three Indonesian representatives and the Australian from the WASHINGTON transferred to the ATLANTIS II. Some heat flow gear was transferred to ATLANTIS II. On station 22 out the bottom surface was a smooth, gentle, slightly downward slope with sediment varying in thickness from 0.5 sec to about 0.1 sec over a gently rolling subbottom reflector. During the last two hours of the station the WASHINGTON passed over a slight rise into deepening water with an irregular bottom and no visible subbottom reflector.

The WASHINGTON had another cracked cylinder liner on one engine and we did not know how long we would be able to go at full speed. It would not be possible for the WASHINGTON to stop and receive another station at the end of station 22 as we had to arrive at the current meter drop of leg 7 on time and it might be necessary to proceed there at reduced speed using only one engine. The outgoing side of station 22 was continued until the records became too weak, after which ATLANTIS II departed to Ujung Pandang via Ambon, and the WASHINGTON to Guam via the current meter site. A neuston tow was taken at the end of station 22.

September 23-24 WASHINGTON ran to the current meter site between the Sula Islands and Obi Island. The meters came up when and as expected and were retrieved. There were two good records which showed a steady strong flow of 20 and 24 cm/sec.

September 24-26 Current meter site to Sonsorol Island. During the run to Guam after the current meter pick-up, five one-way sonobuoy refraction stations were shot. Station 23, September 24, was in the Molucca Sea west of Halmahera Island. Station 24, September 24-25, was in the northern Molucca Sea. Station 25, September 25, was in a smooth sediment area north of Halmahera. An extremely thick layer of low-velocity material (8 to 10 km) was found beneath Station 24, overlying rock with basement velocities. This thick layer probably corresponds to the melange material reported on reflection data from leg 4. The set of sonobuoys on Stations 24 and 25 were worked up together, and show extreme thinning of the low-velocity material approximately at the boundary between the melange and the smooth sediments north of the north tip of Halmahera. After crossing the ridge at the north end of Halmahera, we crossed the Philippine Trench, which had no sediment in the bottom in this area, across some hills and sediment-filled basins out onto the Philippine Plate. Beyond the last hill we shot station 26. Station 27, September 26, was started approximately 5 hours before reaching Sonsorol Island. After passing over a hill we shot upslope to the island. One neuston tow was taken September 25.

September 26-29 Sonsorol Island to Guam. This was a direct run to Guam passing within sight of Ulithi Island. The scientific party were occupied by some shipboard reduction of data and preparing equipment for shipment to San Diego. Two neuston tows were taken September 27. Underway observations were secured the evening of September 29. WASHINGTON entered Apra Harbor the morning of September 30.

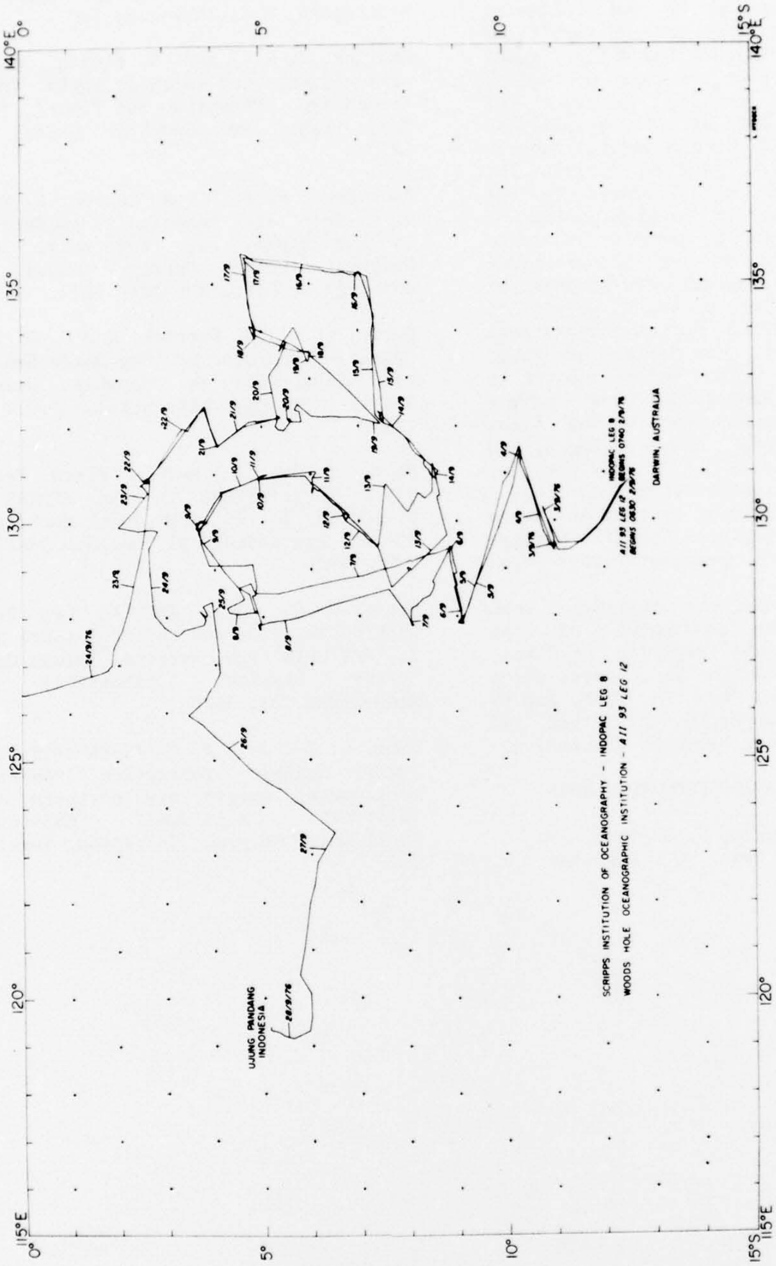


Fig. 7. Combined tracks of R/V THOMAS WASHINGTON and R/V ATLANTIS II in the Banda Sea area for INDOPAC 8 and A II 93 Leg 12.

ACKNOWLEGEMENTS

Work carried out on INDOPAC legs 4 through 8 was supported by the following contracts and grants to the University of California: National Science Foundation grant OCE 75-19148 for support of the geological program under Hawkins on leg 4; grant OCE 75-19387 for support of the geophysical program on legs 4 and 8, and partial support of reflection work on legs 6 and 7; grant INT 76-14749 for travel costs related to the Sino-American cooperative program on leg 5; grant OCE 74-22089 for the studies of canyon currents under Shepard on leg 6; grant OCE 76-02036 for the geological and geophysical program under Eli Silver on leg 7; grants OCE 74-01830 and OCE 74-02888 for ship operations and technical support. The Office of Naval Research supported work under contracts N00014-75-C-0749 and N00014-75-C-0704 for use of a long array for measurements of sea floor sound transmission under Shor on leg 5, and under contract N00014-75-C-0152 for physical oceanographic studies under Patzert on legs 7 and 8. The International Program of Ocean Drilling (NSF) supported drilling site surveys on leg 5, through a purchase order from Columbia University.

Other support for the programs of work was provided by the government of the Philippine Republic, the Republic of China, Indonesia, and India, by the U.S. Naval Bases at Guam and Subic Bay, by the CCOP, and by individuals who volunteered their time and efforts to assist in the research program.

PUBLICATIONS RESULTING FROM THIS WORK

Bowin, C.O., G.M. Purdy, G. G. Shor, Jr., L. Lawver, H.M.S. Hartono, C. Johnston, F. Chamalaun, and J. Sunderland, Geophysical study of the Banda Arc, Indonesia, (abstract) Am. Geophys. Union Spring Annual Meeting, Washington, D.C., May-June 1977.

Hawkins, J. W., and R. Batiza., Metabasites, metasediments and volcanic rocks from the Yap Trench-Arc: Obducted sea floor?, (abstract), EOS, Trans. Am. Geophys. Union, 57, 1021, 1977.

Jacobson, R. S., L. A. Lawver, K. Becker, and G. G. Shor, Jr., Anomalously uniform heat flow in the Banda Sea, (abstract), Am. Union Geophys. Union Spring Annual Meeting, Washington, D.C., May-June 1977.

Purdy, G. M., R. Detrick, and G. G. Shor, Jr., Crustal structure of the Banda Sea and Weber Deep, (abstract) Am. Geophys. Union Spring Annual Meeting, Washington, D.C., May-June 1977.

Shor, G. G., Jr., Marine Field Programs by U.S. Institutions in the SEATAR project, presented to IOC-CCOP Joint Working Group on SEATAR, Proceedings of the 13th Session of the CCOP, 1976.

Shor, G. G., Jr., INDOPAC Leg 5, R/V T. WASHINGTON, SIO, and Philippine Sea Survey Leg 3, R/V CHIU LIEN, National Taiwan University, Marine Physical Laboratory Technical Memorandum 285, 1977.

Shor, G. G., Jr., R. M. Kieckhefer, and G. M. Purdy, Seismic refraction studies of the continental margin off northern Australia, (abstract) AAPG/UTMSI Colloquium on Continental Margins, Galveston, Texas, January 1977.

INDOPAC EXPEDITION

APPENDIX

Personnel, Sample Locations and Statistics

STATISTICS

Distances, km	Leg 4	Leg 5	Leg 6	Leg 7	Leg 8
Total steaming	4718	5713	3677	5306	8597
Bathymetry	4622	5578	3677	5204	8502
Magnetics	4357	4138	3187	4759	7227
Gravity	4718	5713	3677	5306	8597
Airgun reflection	4260	4818	3206	4305	6986

For information on details of the data and samples listed on the following pages, and on availability of copies of data or sections of samples, contact S.M. Smith, Geological Data Center, Scripps Institution of Oceanography, La Jolla, Calif. 92093 (Phone: 714-452-2752).

PERSONNEL

Leg 4

Hawkins, James	Chief Scientist	Scripps Institution of Oceanog.
Wilson, Robert	Resident Tech	Scripps Institution of Oceanog.
Elston, Marvin	Computer Tech	Scripps Institution of Oceanog.
McKee, Joseph	Airgun Tech	Scripps Institution of Oceanog.
Batiza, Rodey	Student	Scripps Institution of Oceanog.
Chao, Benjamin	Student	Scripps Institution of Oceanog.
Dixon, Timothy	Student	Scripps Institution of Oceanog.
Dorman, LeRoy	Assoc. Res. Geophys.	Scripps Institution of Oceanog.
Jacobson, Randall	Student	Scripps Institution of Oceanog.
Kieckhefer, Robert	Student	Scripps Institution of Oceanog.
Lawver, Lawrence	Postgrad. Res. Geophys.	Scripps Institution of Oceanog.
O'Neill, Paul	Lab Asst.	Scripps Institution of Oceanog.
Stern, Robert	Student	Scripps Institution of Oceanog.
Whitney, William	Senior Eng.	Scripps Institution of Oceanog.

Leg 5

Shor, George	Chief Scientist	Scripps Institution of Oceanog.
Coatsworth, James	Resident Tech	Scripps Institution of Oceanog.
Elston, Marvin	Computer Tech	Scripps Institution of Oceanog.
McKee, Joseph	Airgun Tech	Scripps Institution of Oceanog.
Bodvarsson, Gudrun	Lecturer	Inst. Oceanog., Nat. Taiwan U.
Chang, Tien-Hsiang	Tech	Inst. Oceanog., Nat. Taiwan U.
Chao, Benjamin	Student	Scripps Institution of Oceanog.
Huang, Tung-Wuu	Postdoc Fellow	Inst. Oceanog., Nat. Taiwan U.
Jacobson, Randall	Student	Scripps Institution of Oceanog.
Kieckhefer, Robert	Student	Scripps Institution of Oceanog.
Lawver, Lawrence	Postgrad. Res. Geophys.	Scripps Institution of Oceanog.
Louden, Keith	Postdoc Fellow	Mass. Inst. of Tech.
Mc Gowan, Delpha	Refraction Tech	Scripps Institution of Oceanog.
Ogg, James	Student	Scripps Institution of Oceanog.
O'Neill, Paul	Refraction Tech	Scripps Institution of Oceanog.
Shor, Elizabeth	Lab Helper	Scripps Institution of Oceanog.
Sullivan, Gary	Staff Res. Assoc.	Scripps Institution of Oceanog.
Sverdrup, Keith	Student	Scripps Institution of Oceanog.
Vitek, John	Volunteer	Scripps Institution of Oceanog.
Whitney, William	Senior Eng.	Scripps Institution of Oceanog.

Leg 6

Shepard, Francis	Chief Scientist	Scripps Institution of Oceanog.
Coatsworth, James	Resident Tech	Scripps Institution of Oceanog.
Moe, Ronald	Computer Eng.	Scripps Institution of Oceanog.
Battey, Roger	Airgun Tech	Scripps Institution of Oceanog.
Bibee, L. Dale	Student	Scripps Institution of Oceanog.
Jacobson, Randall	Student	Scripps Institution of Oceanog.
Kieckhefer, Robert	Student	Scripps Institution of Oceanog.
Louden, Keith	Postdoc Fellow	Mass. Inst. of Tech.
Marshall, Neil	Staff Res. Assoc.	Scripps Institution of Oceanog.
McGowan, Delpha	Refraction Tech	Scripps Institution of Oceanog.
Ogg, James	Student	Scripps Institution of Oceanog.
O'Neill, Paul	Refraction Tech	Scripps Institution of Oceanog.
Pueblos, Valentino	Lieutenant	Philippine Bureau of Coast & Geodetic Survey
Shor, Elizabeth	Lab Helper	Scripps Institution of Oceanog.
Shor, George	Prof. of Marine Geophys.	Scripps Institution of Oceanog.
Sonido, Ernesto	Prof. of Geol.	Univ. of Manila, P.I.
Sullivan, Gary	Staff Res. Assoc.	Scripps Institution of Oceanog.
Sverdrup, Keith	Student	Scripps Institution of Oceanog.

Leg 7

Silver, Eli	Chief Scientist	Univ. of Calif., Santa Cruz
Coatsworth, James	Resident Tech	Scripps Institution of Oceanog.
Moe, Ronald	Computer Eng.	Scripps Institution of Oceanog.
Battey, Roger	Airgun Tech	Scripps Institution of Oceanog.
Chao, Benjamin	Student	Scripps Institution of Oceanog.
Costello, James	Hydrographic Tech	Scripps Institution of Oceanog.
Ferreira, Simon	Current Meter Tech	Scripps Institution of Oceanog.
Galera, Lorenzo	Lieutenant	Philippine Coast Guard
Golding, Terry	Geologist	C.S.I.R.O., Australia
Jacobson, Randall	Student	Scripps Institution of Oceaong.
Joyodiwiryo, Yoko	Geophysicist	Geological Survey of Indonesia
Karta, Komar	Geologist	Indonesian Petroleum Institute
McGowan, Delpha	Refraction Tech	Scripps Institution of Oceanog.
Moore, J. Casey	Asst. Prof. Earth Science	Univ. of Calif., Santa Cruz
Moreton, David	Student	Monash Univ., Melbourne, Aust.
Muus, David	Hydrographic Tech	Scripps Institution of Oceanog.
O'Neill, Paul	Refraction Tech	Scripps Institution of Oceanog.
Patzert, William	Asst. Res. Oc.	Scripps Institution of Oceanog.
Utomo, Driyo	Captain	Indonesian Navy Hydrographic Office

Leg 8

Shor, George	Chief Scientist	Scripps Institution of Oceanog.
Coatsworth, James	Resident Tech	Scripps Institution of Oceanog.
Moe, Ronald	Computer Eng.	Scripps Institution of Oceanog.
Battey, Roger	Airgun Tech	Scripps Institution of Oceanog.
McKee, Joseph	Airgun Tech	Scripps Institution of Oceanog.
Berry, Ronald	Student	Flinders Univ., Australia
Chao, Benjamin	Student	Scripps Institution of Oceanog.
Das Gupta, Tirthankar	Geologist	Geological Survey of India
Ferreira, Simon	Current Meter Tech	Scripps Institution of Oceanog.
Jacobson, Randall	Student	Scripps Institution of Oceanog.
Joyodiwiryo, Yoko	Geophysicist	Geological Survey of Indonesia
Karta, Komar	Geologist	Indonesian Petroleum Institute
Kieckhefer, Robert	Student	Scripps Institution of Oceanog.
McGowan, Delpha	Refraction Tech	Scripps Institution of Oceanog.
Muus, David	Hydrographic Tech	Scripps Institution of Oceanog.
O'Neill, Paul	Refraction Tech	Scripps Institution of Oceanog.
Phillips, Richard	Prof. Env. Sci.	Univ. of San Diego
Raitt, Russell	Prof. of Geophys.	Scripps Institution of Oceanog.
Rao, B.R.	Geologist	Geological Survey of India
Shor, Elizabeth	Lab Helper	Scripps Institution of Oceanog.
Utomo, Driyo	Captain	Indonesian Navy Hydrographic Office

SAMPLE LOCATIONS

Dredge hauls

No.	starting position Latitude	Longitude
Leg 4		
1	11-15.4N	139-21.0E
2	10-01.8N	138-23.0E
3	08-32.9N	135-52.3E
4	07-27.3N	136-24.4E
5	07-46.7N	134-46.7E
6	07-26.1N	133-43.0E
7	08-56.8N	138-01.3E
8	09-40.6N	138-20.5E
9	10-48.9N	138-36.1E
Leg 7		
10	01-00.4N	125-13.3E

Cores

Leg 4		
G-1	08-16.4N	135-53.6E
Leg 5		
P-1	18-10.2N	141-02.7E
PG-1	18-10.2N	141-02.7E
P-2	17-38.1N	137-44.9E
PG-2	17-38.1N	137-44.9E
P-3	18-05.9N	133-03.0E
PG-3	18-05.9N	133-03.0E
G-2	18-33.5N	131-44.6E
G-3	21-13.4N	125-39.5E
Leg 6		
G-4	17-30.2N	120-21.7E
G-5	17-28.1N	120-21.0E
G-6	17-31.6N	120-19.1E
G-7	17-31.0N	120-17.0E
G-8	17-30.2N	120-12.7E
G-9	17-44.3N	120-20.2E
G-10	17-42.7N	120-15.7E
G-11	17-42.8N	120-12.5E
G-12	17-43.0N	120-13.3E
G-13	17-45.2N	120-10.9E
G-14	17-23.3N	120-12.2E
G-15	17-22.4N	120-12.2E
G-16	17-16.5N	120-16.8E
G-17	17-16.5N	120-17.9E
G-18	17-12.9N	120-17.4E
G-19	17-09.6N	120-19.5E
G-20	17-24.3N	120-21.6E
G-21	17-24.2N	120-25.5E
G-22	17-26.9N	120-24.5E
G-23	17-27.1N	120-24.5E
G-24	17-27.0N	120-22.0E
G-25	17-31.7N	120-09.7E
G-26	17-40.4N	120-08.6E
Leg 8		
G-27	08-54.2S	129-28.0E
G-28	04-52.7S	128-07.2E
G-29	04-09.2S	130-35.4E
G-30	06-05.6S	131-02.3E
G-31	07-19.9S	129-27.5E
G-32	08-31.2S	131-08.2E
G-33	04-36.3S	135-32.3E
G-34	05-59.4S	133-33.8E
G-35	05-19.1S	132-12.8E
G-36	04-07.0S	131-36.8E
G-37	03-45.9S	132-21.3E

Heat flow

Leg 4		
1	08-16.5N	135-53.5E
2	07-53.3N	134-02.3E
Leg 5		
3	16-01.3N	140-54.3E
4	18-07.9N	141-05.2E
5	17-58.1N	137-00.9E
6	18-03.2N	133-09.6E
7	18-32.9N	131-43.9E
Leg 8		
12	08-54.4S	129-28.9E
13	04-52.2S	128-07.4E
14	06-04.6S	131-00.8E
15	07-21.9S	129-29.4E
16	08-31.5S	131-07.4E
17	05-59.5S	133-32.4E
18	03-44.8S	132-20.2E

SEISMIC REFRACTION STATIONS

Leg 5

Two ship refraction with CHIU LIEN

			Position	
1	Receive	Begin	15-58.8N	140-51.4E
		End	15-56.9N	140-45.3E
2	Shoot	Begin	18-08.9N	145-04.8E
		End	17-37.6N	145-10.6E
3	Receive	Begin	17-34.7N	145-09.1E
		End	17-34.6N	145-05.0E
4	Receive	Begin	17-45.0N	144-51.3E
		End	17-43.9N	144-47.4E
5	Shoot	Begin	17-43.2N	144-47.2E
		End	18-10.3N	144-36.5E
6	Shoot	Begin	18-12.3N	144-28.7E
		End	17-45.5N	144-37.4E
7	Shoot	Begin	18-02.3N	142-29.7E
		End	18-06.7N	141-43.5E
8	Shoot	Begin	18-06.7N	141-43.0E
		End	18-07.3N	141-08.1E
9	Receive	Begin	18-07.6N	141-05.6E
		End	18-09.7N	141-03.1E
11	Receive	Begin	17-57.9N	139-47.0E
		End	17-58.1N	139-19.4E
12	Shoot	Begin	18-03.2N	138-00.4E
		End	17-27.4N	137-37.9E
13	Receive	Begin	17-26.3N	137-34.5E
		End	17-27.0N	137-30.6E
14	Receive	Begin	17-58.4N	136-59.5E
		End	17-58.8N	136-59.1E
15	Receive	Begin	17-58.8N	136-59.0E
		End	17-59.5N	136-58.2E
16	Receive	Begin	18-00.9N	136-57.1E
		End	18-02.5N	136-56.2E
17	Receive	Begin	18-02.6N	136-56.1E
		End	18-06.3N	136-54.5E
18	Shoot	Begin	18-00.4N	134-25.8E
		End	18-02.5N	133-48.5E
19	Shoot	Begin	18-02.5N	133-47.5E
		End	18-02.6N	133-136E
20	Receive	Begin	18-03.0N	133-10.9E
		End	18-04.1N	133-08.0E
21	Receive	Begin	18-04.1N	133-07.9E
		End	18-05.5N	133-04.0E
22	Receive	Begin	18-21.1N	131-59.0E
		End	18-23.8N	131-55.0E
23	Receive	Begin	18-24.9N	131-53.1E
		End	18-29.9N	131-45.1E
24	Shoot	Begin	20-50.0N	127-07.3E
		End	21-03.5N	126-29.5E
25	Shoot	Begin	21-03.8N	126-26.7E
		End	21-12.0N	125-42.2E
26	Receive	Begin	21-13.1N	125-39.5E
		End	21-15.2N	125-38.8E
28	Receive	Begin	25-18.8N	124-26.4E
		End	25-20.1N	124-26.3E
29	Receive	Begin	25-20.2N	124-26.3E
		End	25-23.4N	124-26.0E
30	Receive	Begin	25-28.0N	124-26.3E
		End	25-35.0N	124-29.5E
31	Receive	Begin	25-22.6N	123-48.1E
		End	25-23.5N	123-50.8E
32	Receive	Begin	25-23.6N	123-50.9E
		End	25-30.6N	123-51.4E

Leg 8

Two ship refraction with ATLANTIS II

1	Receive	Begin	10-57.4S	129-27.9E
		End	10-54.4S	129-30.8E
2	Shoot	Begin	10-51.2S	129-36.6E
		End	10-17.6S	131-31.5E
3	Shoot	Begin	09-07.4S	127-52.6E
		End	08-53.5S	129-23.9E
4	Receive	Begin	08-54.2S	129-27.8E
		End	08-52.2S	129-28.8E
5	Receive	Begin	04-52.8S	128-07.4E
		End	04-50.1S	128-08.3E
6	Shoot	Begin	03-40.7S	129-46.3E
		End	04-09.0S	130-32.7E
7	Receive	Begin	04-09.3S	130-35.3E
		End	04-07.9S	130-38.9E
8	Shoot	Begin	04-12.1S	130-39.9E
		End	06-04.2S	131-04.1E

Leg 8 - cont.

9	Receive	Begin	06-02.7S	130-56.7E
		End	06-01.8S	130-40.2E
10	Shoot	Begin	06-05.2S	130-43.2E
		End	07-19.2S	129-31.3E
11	Receive	Begin	07-21.1S	129-29.2E
		End	07-23.4S	129-30.6E
12	Receive	Begin	08-30.9S	131-10.7E
		End	08-33.8S	130-58.1E
13	Shoot	Begin	08-34.2S	130-55.4E
		End	07-21.7S	132-13.1E
14	Shoot	Begin	06-59.9S	135-13.1E
		End	04-38.6S	135-34.2E
15	Receive	Begin	04-35.2S	135-32.1E
		End	04-39.5S	135-37.3E
16	Shoot	Begin	04-53.8S	133-55.8E
		End	05-34.7S	133-37.8E
17	Receive	Begin	05-59.3S	133-33.4E
		End	05-58.8S	133-24.7E
18	Receive	Begin	05-19.8S	132-11.5E
		End	05-19.6S	132-09.3E
19	Shoot	Begin	05-15.3S	132-10.5E
		End	04-07.8S	131-39.0E
20	Receive	Begin	04-06.7S	131-35.8E
		End	04-05.0S	131-35.2E
21	Receive	Begin	03-48.0S	132-23.2E
		End	03-41.8S	132-18.6E
22	Shoot	Begin	03-41.0S	132-16.8E
		End	02-28.1S	129-20.8E

Single ship/Sonobuoy Refraction

23	Begin	00-16.1N	126-29.9E
	End	00-35.3N	126-34.6E
24	Begin	02-14.3N	127-14.8E
	End	02-33.6N	127-39.5E
25	Begin	02-51.5N	128-03.6E
	End	03-02.5N	128-20.7E
26	Begin	04-11.1N	130-03.9E
	End	04-19.5N	130-21.0E
27	Begin	04-54.3N	131-19.9E
	End	05-24.9N	132-15.6E

SALINITY, TEMPERATURE, DEPTH

No.	Depth	Position Latitude	Longitude
Leg 7			
1M	5010M	08-26.4N	121-56.7E
1D	5010M	08-31.5N	121-53.0E
1S	1416M	08-30.6N	121-52.2E
2D	5420M	02-30.7N	122-20.0E
2S	1205M	02-31.4N	122-22.6E
3D	3915M	03-45.0N	126-14.5E
3S	1205M	03-44.7N	126-14.5E
4D	3600M	02-50.1N	127-46.4E
4S	1205M	02-50.9N	127-48.5E
5D	3015M	01-28.3N	127-08.5E
5S	1000M	01-29.4N	127-08.0E
6D	4125M	00-05.8N	124-43.1E
6S	1205M	00-06.8N	124-44.1E
7D	1005M	00-59.1S	126-48.8E
7S	4750M	00-58.4S	126-48.5E
8	1905M	01-48.4S	126-57.8E
9D	5320M	03-14.3S	125-19.9E
9S	1405M	03-15.0S	125-20.1E
10D	4390M	06-27.5S	126-00.2E
10S	1205M	06-26.5S	126-00.3E
11	3750M	07-35.6S	127.49.5E
12	2005M	08-50.2S	128-35.0E
Leg 8			
1D	2135M	08-54.2S	129-28.9E
1S	1000M	08-53.8S	129-28.9E
2S	1500M	04-09.9S	130-35.8E
2D	3905M	04-09.1S	130-36.0E
3D	6000M	06-05.5S	131-03.8E
3S	1200M	06-06.0S	131-02.8E
4S	1620M	08-30.7S	131-11.8E
4D	1605M	08-30.8S	131-10.1E
5D	3560M	05-59.8S	133-32.4E
5S	0600M	06-00.7S	133-32.0E
6	0780M	05-19.8S	132-11.4E
7D	2130M	03-47.8S	132-23.2E
7S	1000M	03-46.9S	132-22.6E

HYDROGRAPHIC CASTS

No.	Position Latitude	Longitude
Leg 7		
1M	08-28.1N	121-55.4E
1D	08-32.3N	121-52.3E
1S	08-30.2N	121-52.1E
2D	02-31.1N	122-20.8E
2S	02-32.0N	122-23.2E
3D	03-45.1N	126-14.6E
3S	03-44.3N	126-15.0E
4D	02-50.3N	127-47.4E
4S	02-51.1N	127-48.7E
5D	01-28.9N	127-08.5E
5S	01-29.3N	127-07.7E
6D	00-06.1N	124-43.6E

Leg 7 - cont.

6S	00-06.8N	124-45.0E
7D	00-58.8S	126-48.9E
7S	00-58.3S	126-48.6E
8	01-48.1S	126-57.7E
9D	03-14.9S	125-20.2E
9S	03-15.0S	125-20.1E
10D	06-27.3S	125-59.8E
10S	06-26.5S	126-00.2E
11	07-36.2S	127-49.7E
12	08-52.6S	128-35.5E

Leg 8

1D	08-52.8S	129-28.6E
1S	08-52.8S	129-28.6E
2S	04-09.1S	130-35.7E
2D	04-09.1S	130-36.3E
3D	06-06.0S	131-03.1E
3S	06-05.9S	131-02.7E
3*	06-05.7S	131-02.5E
4S	08-31.0S	131-11.8E
4D	08-31.0S	131-11.8E
5D	06-00.2S	133-32.2E
5S	06-00.8S	133-31.9E
6	05-20.0S	132-10.9E
7D	03-47.5S	132-23.0E
7S	03-46.6S	132-22.2E

* Bottles on gravity core G-30.

CURRENT MEASUREMENT

Time GMT	Date D.M.Y.	Sta. No.		Latitude	Longitude
Leg 6					
1428	2 876	103	Begin	17-30.0N	120-21.6E
2235	6 876		End	17-29.8N	120-21.7E
1516	2 876	104	Begin	17-27.6N	120-19.9E
2349	6 876		End	17-26.9N	120-20.0E
0429	7 876	105	Begin	17-43.3N	120-21.4E
2225	10 876		End	17-41.9N	120-20.6E
0638	7 876	106	Begin	17-43.4N	120-11.0E
2340	10 876		End	17-40.5N	120-13.7E
Leg 7/8					
2337	24 876	1	Begin	01-50.2S	127-00.2E
1705	23 976		End	01-49.6S	127-00.8E
0046	25 876	2	Begin	01-48.8S	126-57.5E
1838	23 976		End	01-48.5S	126-58.7E
0207	25 876	3	Begin	01-47.1S	126-54.3E
2048	23 976		End	01-46.2S	126-55.3E

MIDWATER TRAWLS

Leg 5			
3	Begin	25-36.3N	124-30.9E
	End	25-34.3N	124-26.9E
Leg 6			
4	Begin	17-36.7N	119-54.5E
	End	17-48.4N	119-55.4E
Leg 7			
5	Begin	04-32.0S	125-31.1E
	End	04-52.7S	125-30.3E
Leg 8			
6	Begin	05-21.4S	133-34.3E
	End	05-30.7S	133-47.3E

Neuston tows were taken on all legs; 2 on Leg 4, 19 on Leg 5, 15 on Leg 6, 10 on Leg 7 and 24 on Leg 8. Bathythermographs were taken as follows: 15 on Leg 4, 33 on Leg 5 and 25 on Leg 8.

Marine Physical Laboratory
MPL-U-30/77

CRUISE REPORT, INDOPAC EXPEDITION, LEGS 4, 5, 6, 7, AND 8 edited by George G. Shor, Jr. and Stuart M. Smith, University of California, San Diego, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, California 92152. SIO Reference 77-5, 31 March 1977.

In the summer of 1976, the R/V THOMAS WASHINGTON of the Scripps Institution of Oceanography carried out a series of geophysical, geological, and physical oceanographic programs in the marginal basins between the Pacific Ocean and Asia, on legs 4 through 8 of INDOPAC Expedition. Work was in the Philippine, South China, Sulu, Celebes, Molucca, Banda, and Arafura Seas. This report includes chronology of work, cruise tracks, lists of samples, stations, and observations, and some preliminary results. Among the significant preliminary results were the sampling of metamorphic rocks along the Yap island arc; the observation of anomalous crustal structure beneath the Philippine Sea and the Okinawa Trough; measurement of about 10 km of melange material in the Molucca Sea, which at the edges thrusts up over the arcs on either side of the Molucca Sea; observation of continental crust beneath the

(continued)

IIIa. Marine Geophysics

1. George G. Shor, Jr.
2. Stuart M. Smith

Sponsored by
Office of Naval Research
and
National Science Foundation

UNCLASSIFIED

Marine Physical Laboratory
MPL-U-30/77

CRUISE REPORT, INDOPAC EXPEDITION, LEGS 4, 5, 6, 7, AND 8 edited by George G. Shor, Jr. and Stuart M. Smith, University of California, San Diego, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, California 92152. SIO Reference 77-5, 31 March 1977.

In the summer of 1976, the R/V THOMAS WASHINGTON of the Scripps Institution of Oceanography carried out a series of geophysical, geological, and physical oceanographic programs in the marginal basins between the Pacific Ocean and Asia, on legs 4 through 8 of INDOPAC Expedition. Work was in the Philippine, South China, Sulu, Celebes, Molucca, Banda, and Arafura Seas. This report includes chronology of work, cruise tracks, lists of samples, stations, and observations, and some preliminary results. Among the significant preliminary results were the sampling of metamorphic rocks along the Yap island arc; the observation of anomalous crustal structure beneath the Philippine Sea and the Okinawa Trough; measurement of about 10 km of melange material in the Molucca Sea, which at the edges thrusts up over the arcs on either side of the Molucca Sea; observation of continental crust beneath the

(continued)

IIIa. Marine Geophysics

1. George G. Shor, Jr.
2. Stuart M. Smith

Sponsored by
Office of Naval Research
and
National Science Foundation

UNCLASSIFIED

Marine Physical Laboratory
MPL-U-30/77

CRUISE REPORT, INDOPAC EXPEDITION, LEGS 4, 5, 6, 7, AND 8 edited by George G. Shor, Jr. and Stuart M. Smith, University of California, San Diego, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, California 92152. SIO Reference 77-5, 31 March 1977.

In the summer of 1976, the R/V THOMAS WASHINGTON of the Scripps Institution of Oceanography carried out a series of geophysical, geological, and physical oceanographic programs in the marginal basins between the Pacific Ocean and Asia, on legs 4 through 8 of INDOPAC Expedition. Work was in the Philippine, South China, Sulu, Celebes, Molucca, Banda, and Arafura Seas. This report includes chronology of work, cruise tracks, lists of samples, stations, and observations, and some preliminary results. Among the significant preliminary results were the sampling of metamorphic rocks along the Yap island arc; the observation of anomalous crustal structure beneath the Philippine Sea and the Okinawa Trough; measurement of about 10 km of melange material in the Molucca Sea, which at the edges thrusts up over the arcs on either side of the Molucca Sea; observation of continental crust beneath the

(continued)

IIIa. Marine Geophysics

1. George G. Shor, Jr.
2. Stuart M. Smith

Sponsored by
Office of Naval Research
and
National Science Foundation

UNCLASSIFIED

Marine Physical Laboratory
MPL-U-30/77

CRUISE REPORT, INDOPAC EXPEDITION, LEGS 4, 5, 6, 7, AND 8 edited by George G. Shor, Jr. and Stuart M. Smith, University of California, San Diego, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, California 92152. SIO Reference 77-5, 31 March 1977.

In the summer of 1976, the R/V THOMAS WASHINGTON of the Scripps Institution of Oceanography carried out a series of geophysical, geological, and physical oceanographic programs in the marginal basins between the Pacific Ocean and Asia, on legs 4 through 8 of INDOPAC Expedition. Work was in the Philippine, South China, Sulu, Celebes, Molucca, Banda, and Arafura Seas. This report includes chronology of work, cruise tracks, lists of samples, stations, and observations, and some preliminary results. Among the significant preliminary results were the sampling of metamorphic rocks along the Yap island arc; the observation of anomalous crustal structure beneath the Philippine Sea and the Okinawa Trough; measurement of about 10 km of melange material in the Molucca Sea, which at the edges thrusts up over the arcs on either side of the Molucca Sea; observation of continental crust beneath the

(continued)

IIIa. Marine Geophysics

1. George G. Shor, Jr.
2. Stuart M. Smith

Sponsored by
Office of Naval Research
and
National Science Foundation

UNCLASSIFIED

MPL-U-30/77

Timor-Tanimbar-Aru troughs. A turbidity current was recorded by current meters off the Abra delta of Luzon. Strong south-flowing currents were recorded showing transport of water through Lifamatola Strait from the Pacific to the Indian Ocean. Work on leg 5 was in cooperation with the R/V CHIU LIEN of National Taiwan University; work on leg 8 was in cooperation with the R/V ATLANTIS II of Woods Hole Oceanographic Institution.

MPL-U-30/77

Timor-Tanimbar-Aru troughs. A turbidity current was recorded by current meters off the Abra delta of Luzon. Strong south-flowing currents were recorded showing transport of water through Lifamatola Strait from the Pacific to the Indian Ocean. Work on leg 5 was in cooperation with the R/V CHIU LIEN of National Taiwan University; work on leg 8 was in cooperation with the R/V ATLANTIS II of Woods Hole Oceanographic Institution.

MPL-U-30/77

Timor-Tanimbar-Aru troughs. A turbidity current was recorded by current meters off the Abra delta of Luzon. Strong south-flowing currents were recorded showing transport of water through Lifamatola Strait from the Pacific to the Indian Ocean. Work on leg 5 was in cooperation with the R/V CHIU LIEN of National Taiwan University; work on leg 8 was in cooperation with the R/V ATLANTIS II of Woods Hole Oceanographic Institution.

MPL-U-30/77

Timor-Tanimbar-Aru troughs. A turbidity current was recorded by current meters off the Abra delta of Luzon. Strong south-flowing currents were recorded showing transport of water through Lifamatola Strait from the Pacific to the Indian Ocean. Work on leg 5 was in cooperation with the R/V CHIU LIEN of National Taiwan University; work on leg 8 was in cooperation with the R/V ATLANTIS II of Woods Hole Oceanographic Institution.

DISTRIBUTION LIST

Chief of Naval Research
Department of the Navy
Arlington, Virginia 22217
  Code 200 (1)
  Code 222 (2)
  Code 102IP (1)
  Code 1020SC (1)
  Code 460 (1)
  Code 480 (1)
  Code 481 (1)
  Code 486 (1)

Director
Office of Naval Research
  Branch Office
1030 East Green Street
Pasadena, Calfornia 91101 (1)

Commander
Naval Sea Systems Command
Washington, D.C. 20362
  Code 03E (1)
  Code 034 (1)
  Code 0342 (1)
  Code 036 (1)
  Code 06H1 (1)
  Code 06H2 (1)
  Code 09G3 (1)
  Code 92 (1)
  Code 662C14 (1)
  PMS 395-4 (1)
  PMS 402 B (1)

Commander
Naval Air Systems Command
Washington, D.C. 20361
  Code 370 (1)
  Code 264 (1)

Commander
Naval Electronics
  Systems Command
Washington, D.C. 20360
  Code PME-124 (1)

Chief of Naval Material
Department of the Navy
Washington, D.C. 20360
  Code PM-4 (1)
  Code 034 (1)
  Code ASW121 (1)

Chief of Naval Operations
Department of the Navy
Washington, D.C. 20350
  Code Op 03 (1)
  Code Op 32 (1)
  Code Op 098 (1)
  Code Op 02 (1)
  Code Op 095 (1)
  Code Op 23 (1)
  Code Op 967 (1)

Commanding Officer
Naval Ocean Research &
  Development Activity (NORDA)
National Space Technology Laboratories
Bay St. Louis, Mississippi 39529
  Code 100 (1)
  Code 460 (1)
  Code 500 (1)

Oceanographer of the Navy
The Hoffman Building
200 Stoval Street
Alexandria, Virginia 22332 (1)

Director Strategic Systems
  Projects Office (PM-1)
Department of the Navy
Washington, D.C. 20360
  Code NSP-20 (1)

Director
Defense Research & Engineering
The Pentagon
Washington, D.C. 20301
  Assistant Director (Sea
  Warfare Systems) (1)

Assistant Secretary of the Navy
(Research & Development)
Department of the Navy
Washington, D.C. 20350 (1)

U.S. Naval Oceanographic Office
Washington, D.C. 20373
  Code 1640 (1)
  Code 3440 (1)

Commander Operational Test &
  Evaluation Force
U.S. Naval Base
Norfolk, Virginia 23511 (1)

Commander, Submarine Force
U.S. Pacific Fleet
Fleet Post Office
San Francisco, California 96601 (1)

Commander
Submarine Group FIVE
Fleet Station Post Office
San Diego, California 92132 (1)

Commander
Third Fleet
U.S. Pacific Fleet, FPO
San Francisco, California 96610 (1)

Commander
Submarine Development Group ONE
Fleet Post Office
San Diego, California 92132 (1)

Commander
Submarine Development Group TWO
Naval Submarine Base-New London
Groton, Connecticut 06340 (1)

Commander, Surface Force
U.S. Atlantic Fleet
Norfolk, Virginia 23511 (1)

Commander, Surface Force
U.S. Pacific Fleet
San Diego, California 92155 (1)

Reprint Custodian
Department of Nautical Science
U.S. Merchant Marine Academy
Kings Point, New York 11024 (1)

Deputy Commander
Operational Test &
Evaluation Force, Pacific
U.S. Naval Air Station
San Diego, California 92135 (1)

Commander
Naval Ship Reserach &
Development Center
Bethesda, Maryland 20084 (1)

Naval Civil Engineering Laboratory
Port Hueneme, California 93041
Code L40 (1)
Code L42

Naval Facilities
Engineering Command
Washington, D.C. 20390
Code 03 (1)
Code 032C (1)

Commanding Officer
U.S. Naval Air
Development Center
Warminster, Pennsylvania 18974 (1)

Commander
Naval Ocean Systems Center
San Diego, California 92152
Code 6700 (2)

Officer In Charge
Naval Ship Research &
Development Center
Annapolis, Maryland 21402 (1)

Commanding Officer, Naval
Coastal Systems Laboratory
Panama City, Florida 32401 (1)

Commander
Naval Surface
Combat Systems Center
White Oak
Silver Spring, Maryland 20910 (1)

Director
U.S. Naval Research Laboratory
Washington, D.C. 20375
Code 2620 (1)
Code 2627 (1)
Code 8000 (1)
Code 8100 (1)

Commanding Officer
Naval Underwater Systems Center
Newport, Rhode Island 20844 (1)

Commanding Officer
Naval Underwater Systems Center
New London, Connecticut 06320
Code 900 (1)
Code 905 (1)
Code 910 (1)
Code 930 (1)
Code 960 (1)

Commanding Officer
Naval Training Equipment Center
Orlando, Florida 32813
Tech Library (1)

Chief Scientist
Navy Underwater
Sound Reference Division
U.S. Naval Research Laboratory
P.O. Box 8337
Orlando, Florida 32806

Superintendent
U.S. Naval Postgraduate School
Monterey, California 93940 (1)

Director
Defense Documentation Center
(TIMA), Cameron Station
5010 Duke Street
Alexandria, Virginia 22314 (12)

Executive Secretary
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418 (1)

Supreme Allied Commander
U.S. Atlantic Fleet
ASW Research Center
APO
New York, New York 09019
Via: ONR 210
CNO OP092D1
Secretariat of Military
Information Control
Committee (1)

National Oceanic & Atmospheric
  Administration
6001 Executive Boulevard
Rockville, Maryland 20852 (1)

Director of Naval Warfare Analysis
Institute of Naval Studies
1401 Wilson Boulevard
Arlington, Virginia 22209 (1)

Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202 (1)

Director
Woods Hole
  Oceanographic Institution
Woods Hole, Massachusetts 02543 (1)

Meterological &
  Astrophysical Abstracts
310 E. Capitol Street
Washington, D.C. 20003 (1)

Director
Applied Physics Laboratory
University of Washington
1013 East 40th Street
Seattle, Washington 98105 (1)

National Science Foundation
Washington, D.C. 20550 (1)

Director
Lamont-Doherty
  Geological Observatory
Torrey Cliff
Palisades, New York 10964 (1)

Director
College of Engineering
Department of Ocean Engineering
Florida Atlantic University
Boca Raton, Florida 33431 (1)

Director
Applied Research Laboratory
Pennsylvania State University
P.O. Box 30
State College, Pennsylvania 16802 (1)

Director
University of Texas
Applied Research Laboratory
P.O. Box 8029
Austin, Texas 78712 (1)

TACTEC
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201 (1)

Director
Institute of
  Ocean Science & Engineering
Catholic University of America
Washington, D.C. 20017 (1)

Director
Marine Research Laboratories
c/o Marine Studies Center
University of Wisconsin
Madison, Wisconsin 53706 (1)

Office of Naval Research
  Resident Representative
c/o University of California,
  San Diego
La Jolla, California 92093 (1)

University of California,
  San Diego
La Jolla, California 92093
  MPL Branch Office (5)